UNIVERSIDADE FEDERAL DO PARANÁ

ELIELTON DA SILVA ARAÚJO

PADRÕES ECOLÓGICOS E PROVÁVEIS DETERMINANTES DA COMUNIDADE DE MACRÓFITAS AQUÁTICAS EM UM RIO SUBTROPICAL DE MARÉ

CURITIBA

2017

ELIELTON DA SILVA ARAÚJO

PADRÕES ECOLÓGICOS E PROVÁVEIS DETERMINANTES DA COMUNIDADE DE MACRÓFITAS AQUÁTICAS EM UM RIO SUBTROPICAL DE MARÉ

Dissertação apresentada ao Programa de Pós-Graduação em Ecologia e Conservação da Universidade Federal do Paraná setor de Ciências Biológicas, como requisito parcial à obtenção do grau de Mestre.

Orientador: Prof. Dr. André Andrian Padial

CURITIBA

2017

Universidade Federal do Paraná. Sistema de Bibliotecas.
Biblioteca de Ciências Biológicas.
(Telma Terezinha Stresser de Assis –CRB/9-944)

Araújo, Elielton da Silva
Padrões ecológicos e prováveis determinantes da comunidade de macrófitas aquáticas em um rio subtropical de maré./ Elielton da Silva Araújo.– Curitiba, 2017.
105 f.: il. ; 30cm.

Orientador: André Andrian Padial
Dissertação (Mestrado) - Universidade Federal do Paraná, Setor de Ciências Biológicas. Programa de Pós-Graduação em Ecologia e Conservação.

1. Plantas Aquáticas. 2. Ecologia. 3. Rios. I. Título II. Padial, André Andrian. III. Universidade Federal do Paraná. Setor de Ciências Biológicas. Programa de Pós-Graduação em Ecologia e Conservação.

CDD (20. ed.) 581.92

MINISTÉRIO DA EDUCAÇÃO
SETOR SETOR DE CIENCIAS BIOLOGICAS
UNIVERSIDADE FEDERAL DO PARANÁ
PRÓ-REITORIA DE PESQUISA E PÓS-GRADUAÇÃO
PROGRAMA DE PÓS-GRADUAÇÃO ECOLOGIA E CONSERVAÇÃO

TERMO DE APROVAÇÃO

Os membros da Banca Examinadora designada pelo Colegiado do Programa de Pós-Graduação em ECOLOGIA E CONSERVAÇÃO da Universidade Federal do Paraná foram convocados para realizar a arguição da Dissertação de Mestrado de **ELIELTON DA SILVA ARAUJO** intitulada: **PADRÕES ECOLÓGICOS E PROVÁVEIS DETERMINANTES DA COMUNIDADE DE MACRÓFITAS AQUÁTICAS EM UM RIO SUBTROPICAL DE MARÉ**, após terem inquirido o aluno e realizado a avaliação do trabalho, são de parecer pela sua APROVAÇÃO no rito de defesa.

A outorga do título de mestre está sujeita à homologação pelo colegiado, ao atendimento de todas as indicações e correções solicitadas pela banca e ao pleno atendimento das demandas regimentais do Programa de Pós-Graduação.

Curitiba, 22 de Janeiro de 2018.

ANDRE ANDRIAN PADIAL
Presidente da Banca Examinadora (UFPR)

PRISCILLA DE CARVALHO
Avaliador Externo (UFG)

MARCOS BERGMANN CARLUCCI
Avaliador Interno (UFPR)

AGRADECIMENTOS

Agradeço imensa e carinhosamente aos meus pais, meus irmãos, meus sobrinhos e toda a minha família, sobretudo, à minha mãe Maria Lima. Pelo apoio constante, pelo amor incondicional e principalmente pelo exemplo de cidadão. Muito obrigado por tudo que fazem por mim.

Ao meu incrível orientador, prof Dr. André Padial, por todos os momentos dessa dissertação. Valeu mesmo por aceitar me orientar mesmo sem saber quem eu era. Pelos ensinamentos, pela paciência, compreensão e pela confiança em mim depositada. VOCÊ É TOP!!!

Aos meus sinceros amigos, os mais antigos que sempre me incentivaram e os presentes que Curitiba me deu. Um salve muito grande ao Lipe, Pati, Gusta, Jose, Mamá, Uêdija e mamãe Joice (amo demais vocês)!

Um valeuuuux pra Gisah, Lu, May e Vika. Quatro manas que eu vou levar no meu cuore (pois canceriano) sempre onde estiver nesse mundão. SÍÍÍÍÍÍ, VOCÊS SÃO FODAS! Obrigado por existir na minha lifestyle. <3

Aos meus colegas do LASB e LEC, em especial a Lari Faria e Ju (não sei escrever o sobrenome dela)! Obrigado demais pela recepção, companheirismo e incentivo. Obrigado por cada momento dessa minha estadia na UFPR. Não poderia deixar de agradecer a Raquel do Herbário da UFPR que me ajudou muito com a indexação das exsicatas!

À CAPES pela bolsa concedida e ao CNPq pelo fomento do Projeto no Rio Guaraguaçu. Obrigado pela promoção de uma experiência muito enriquecedora na minha vida pessoal e acadêmica.

Obrigado a todos que de longe ou de perto, direta ou indiretamente contribuíram para a efetivação deste trabalho e para a minha formação.

Ih caraio, somos mestres! Essa dissertação é nossa!

RESUMO

As macrófitas aquáticas consistem no grupo biológico que incluem desde macroalgas até as angiospermas. Tal grupo apresenta grande importância ecológica, sendo consideradas importantes componentes estruturais dos ecossistemas aquáticos. A riqueza, composição e estrutura das comunidades de macrófitas aquáticas são determinadas pelos gradientes ambientais do ecossistema que estão inseridas. A descrição da resposta desta comunidade pode ser feita utilizando a identidade taxonômica e traços funcionais dos indivíduos registrados, resultando em um melhor entendimento dos mecanismos responsáveis pela *community assembly*. A dissertação apresentada teve como objetivo descrever a flora aquática do Rio Guaraguaçu, montar um guia ilustrativo das espécies ocorrentes, bem como analisar a variação espaço-temporal da composição taxonômica e funcional ao longo do gradiente longitudinal do rio em dois anos. O rio está localizado no leste do Estado do Paraná, dentro dos perímetros da Área de Proteção Ambiental de Guaratuba (APA Guaratuba). O material botânico coletado foi herborizado e depositado no Herbário da Universidade Federal do Paraná. A composição taxonômica e funcional da comunidade foi registrada em 16 bancos de macrófitas ao longo de todo o trecho navegável do rio. Tais bancos podem ser categorizados em relação a três diferentes áreas: i) alto impacto antropogênico, ii) baixo impacto e iii) manguezal. Em cada banco de macrófitas, as espécies foram registradas e 11 traços funcionais foram mensurados. Foram calculados os índices de diversidade taxônomica e funcional, bem como a contribuição relativa da variação inter e intraespecífica dos traços para descrever a variação espaço-temporal na variação na organização das comunidades de macrófitas. Foram registradas 47 espécies, representandes de 37 gêneros e 28 famílias botânicas. Foi verificada uma constante e significativa variação espacial na comunidade. Os índices de diversidade das áreas de alto e baixo impacto antropogênico não difereriram entre si e foram significativamente maiores do que os da área de mangue. Porém, a composição taxonômica e funcional da comunidade foi dependente do nível de impacto antropogênico. Houve relação positiva entre a riqueza de espécies e os índices de diversidade funcional, mas não foi evidenciada redundância funcional. A variabilidade intraespecífica dos traços funcionais é o que principalmente determina a riqueza funcional. É evidente que o inventário florístico demonstra uma riqueza expressiva de macrófitas aquáticas e pode contribuir para criação de políticas públicas, uma vez que o rio está inserido numa área prioritária para conservação da biodiversidade. Além disso, o estudo enfatiza a importância das métricas de diversidade funcional, bem como a utilização da variabilidade intraespecífica para o melhor entendimento dos mecanismos de montagem de comunidades de macrófitas aquáticas. Por fim, evidenciamos a baixa variação temporal em um ecossistema altamente dinâmico, no qual a comunidade é fortemente afetada por filtragem ambiental relacionada à salinidade e aos impactos antropogênicos.

Palavras-chave: Plantas aquáticas; variação espaço-temporal; litoral do Paraná; heterogeneidade ambiental; traços funcionais; composição taxonômica e funcional.

ABSTRACT

The biological group of aquatic macrophytes includes from macroalgae to angiosperms. This group is of high ecological importance, being considered as important structural components of aquatic communities. The richness, composition and structure of the aquatic macrophytes communities can be altered by environmental gradients of the ecosystem where they are inserted. The description of the response of this community to the environmental gradients can be made using the taxonomic identity and functional traits of the registered individuals, resulting in a better understanding of the responsible mechanisms for the community assembly. The present dissertation aimed to describe the aquatic flora of the Guaraguaçu River, to create an illustrative guide of species, as well as to analyze the spatial and temporal variation of the taxonomic and functional composition along the longitudinal gradient of the river in two years. This river is located on the coast of the Paraná State, within the perimeters of the Guaratuba Environmental Protection Area (APA Guaratuba). The collected botanical material was herborized and deposited in the Herbarium of the Federal University of Paraná. Taxonomic and functional composition of the community were recorded in 16 macrophyte beds along the whole navigable stretch of the river. This can be categorized in relation to three different areas: i) high anthropogenic impact, ii) low impact and iii) mangrove. In each macrophyte bed, species were recorded and 11 functional traits were measured. The taxonomic and functional diversity indexes, as well as the relative inter- and intraspecific contribution of traits, were measured to describe the spatio-temporal variation in the organization of macrophyte communities. There were 47 species, representing 37 genera and 28 botanical families. There was a constant and significant spatial variation in the community. The diversity indexes of the areas of high and low anthropogenic impact did not differ among themselves and were significantly higher than those of the mangrove area. However, the taxonomic and functional composition of the community was dependent on the level of anthropogenic impact. There was a positive relationship between species richness and functional diversity indexes, but no functional redundancy was evidenced. The intraspecific variability of the functional traits is what mainly determines the functional richness. Therefore, it is evident that the floristic inventory shows an expressive richness of aquatic macrophytes and can contribute to the creation of public policies, since this river is included in a priority area for biodiversity conservation. In addition, the study emphasizes the importance of functional diversity metrics as well as the use of intraspecific variability for a better understanding of the mechanisms of aquatic macrophyte community assembly. Finally, we show the low temporal variation in a highly dynamic ecosystem, in which the community is strongly affected by environmental filtration related to salinity and anthropogenic impacts.

Key-words: Aquatic plants; spatiotemporal variation; Paraná coast; environmental heterogeneity; functional traits; taxonomic and functional composition.

Sumário

Apresentação e Introdução geral

A dissertação apresentada é composta por três capítulos. O primeiro capítulo diz respeito aos dados florísticos do rio Guaraguaçu, onde foram realizadas coletas sazonais e montado um *checklist* das macrófitas aquáticas existentes. Esse capítulo foi estruturado como um artigo a ser submetido ao periódico “Biota Neotropica” (Qualis B2). O segundo capítulo é um manuscrito científico formatado nas normas do periódico “Aquatic Sciences” (Qualis A2) que analisa a variação espaço-temporal da composição taxonômica e funcional ao longo do gradiente longitudinal do rio em dois anos. O terceiro se refere a um guia didático e ilustrativo de todas as espécies coletadas em período fértil, o qual pode subsidiar outras pesquisas e facilitar a identificação das espécies que ocorrem no Rio Guaraguaçu. Esse útlimo material será disponibilizado em PDF, gratuitamente, no site do Laboratório de Análise e Síntese em Biodiversidade – UFPR (https://sites.google.com/site/lablasb/). Para subsidiar a leitura, apresentamos a seguir informações da nossa área e grupo biológico de estudo.

A área de estudo é inserida no bioma Mata Atlântica, um *hotspot* de biodiversidade mundial e um ecossistema que sofre grande degradação histórica (Arroyo-Rodríguez et al., 2015; Melo et al., 2013; Meyers et al., 2000). Há clara ameaça às espécies e processos ecológicos, sobretudo nos ecossistemas aquáticos continentais brasileiros (Barrela et al., 2014; Agostinho et al., 2005). É neste cenário que estão as macrófitas aquáticas, um grupo ecológico que sofre diretamente com fragmentação de habitats.

As macrófitas aquáticas também chamadas de hidrófitas (Raukier, 1934), compreendem as formas macroscópicas de vegetação aquática, incluindo macroalgas, briófitas, pteridófitas e angiospermas. Apresentam grande variedade de nicho ecológico devido a adaptações morfofisiológicas que as permitem sua colonização e estabelecimento em diversos tipos de habitats como tanques, lagos, lagoas, brejos, cachoeiras, rios, riachos, canais, reservatórios, mares e oceanos (Pitelli et al., 2008; Pompeo & Moschini-Carlos, 2003; Thomaz & Bini, 2003; Pott & Pott, 2000; Esteves, 1998; Pedralli, 1990), bem como uma grande importância ecológica, a qual está discutida na literatura de forma expressiva (Bianchini-JR. Et al., 2002; Camargo, 2003; Araujo, et al., 2012; Havel et al., 2015; Grimaldo et al., 2016).

Devido à heterogeneidade filogenética, são preferencialmente classificados quanto ao seu biótipo, denominados genericamente de grupos ecológicos (Esteves, 1998). Para melhor entender esse grupo, foi proposto um esquema que classifica as espécies quanto à sua forma de vida em anfíbias, emergentes, flutuantes livres, flutuantes fixas, submersas livres, submersas fixas e epífitas (Figura 1).

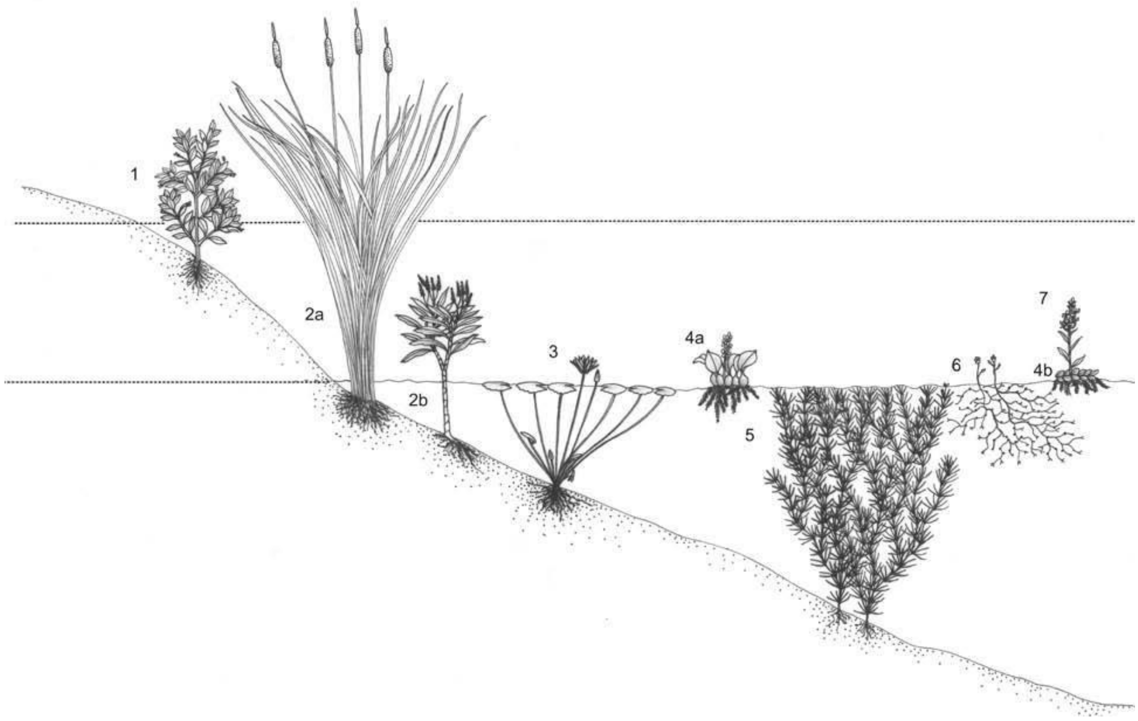


Figura 1: Esquema das formas de vida de macrófitas aquáticas de acordo com Irgang et al. (1984), com adaptações de Campelo et al. (2012). 1(Anfíbia: *Angelonia salicariifolia*); 2ª e 2b(Emergente: *Typha domingensis e Polygonum punctatum*); 3(Flutuante fixa: *Nymphaea caerulea*); 4ª e 4b (Flutuante livre: *Eichhornia crassipes*); 5(Submersa fixa: *Egeria densa*); 6(Submersa livre: *Utricularia gibba*); 7(Epífita: *Habenaria* sp.).

A composição da comunidade vegetal aquática pode variar no espaço e no tempo, ao longo do rio (teoria do rio contínuo) e ao longo dos anos por sucessão ecológica ou sazonalidade, respectivamente. Para ser descrita, pode-se utilizar informações taxonômicas (considerando a identidade taxonômica das espécies) e através de atributos funcionais, o quais consideram o valor e variação das espécies e de suas características que influenciam o funcionamento das comunidades (Hooper et al., 2005). Assim, muitos estudos envolvendo macrófitas aquáticas são levantamentos florísticos, bem como ecológicos relacionados a padrões espaciais e temporais da comunidade aquática.

No que diz respeito aos estudos de cunho ecológico, a ecologia funcional merece destaque. Os estudos de diversidade funcional têm sido realizados no sentido de entender as respostas das comunidades frente à variação ambiental (Asefa et al., 2017; Janes et al., 2017; Crabreba et al., 2015; Fu et al., 2014; Albert et al., 2012; Petchey & Gaston, 2006). Já existem resultados mostrando que a distribuição geográfica das espécies é estritamente relacionada a traços funcionais (Capers, et al., 2010). Exploramos esses aspectos no capítulo 2 dessa dissertação. Boa leitura!

Referências Bibliográficas

AGOSTINHO, A.A.; THOMAZ, S.M.; GOMES, L.C. Conservação da biodiversidade em águas continentais do Brasil. **Megadiversidade** 1(1):70–78. 2005.

ALBERT, C.H.; DE BELLO F.; BOULANGEA T.I.; PELLET, G.; LAVOREL, S.; THUILLER, W. On the importance of intraspecific variability for the quantification of functional diversity. **Oikos** 121:116–126. 2012.

ARAUJO, E.S., SABINO, J.H.F., COTARELLI, V.M., SIQUEIRA-FILHO, J.A., CAMPELO, M.J.A. Riqueza e diversidade de macrófitas aquáticas em mananciais da Caatinga. **Dialogos&Ciencia**, 32, 229-233. 2012.

ARROYO-RODRÍGUEZ, V.; MELO, F.P.; MARTÍNEZ-RAMOS, M.; BONGERS, F.; CHAZDON, R.L.; MEAVE, J.A.; NORDEN, N.; SANTOS, B.A.; LEAL, I.R; TABARELLI, M. Multiple successional pathways in human-modified tropical landscapes: new insights from forest succession, forest fragmentation and landscape ecology research**.** **Biol Rev Camb Philos Soc.**. 92(1):326-340. 2015.

ASEFA, M.; CAO, M.; ZHANG, G.; CI, X.; LI, J.; YANG, J. Environmental filtering structures tree functional traits combination and lineages across space in tropical tree assemblages. **Nature** 7 (132):1-10. 2017.

BARRELA, W.; MARTINS, A.B.; PETRETE-JR, M. RAMIRES, M. Fishes of the southeastern Brazil Atlantic Forest. **Environ Biol Fish**. 97 (12): 1367-1376. 2014.

BIANCHINI JR., I.; PACOBAHYBA, L.D.; CUNHA-SANTINO, M.B. Aerobic and anaerobic decomposition of *Montrichardia arborescens* (L.) Schott. **Acta Limnologica Brasiliensia** 14(3):27-34. 2002.

CABREBA, A.V.; MARTÍNEZ-VILALTA, J.; RETANA, J. Functional trait variation along environmental gradients in temperate and Mediterranean trees. **Global Ecology and Biogeography** 24: 1377–1389. 2015.

CAMARGO, A.F.M.; PEZZATO, M.M.; HENRY-SILVA. G.G. **Fatores limitantes à produção primária de macrófitas aquáticas.** In: Thomaz, S.M. e Bini, L.M. (eds.). Ecologia e manejo de macrófitas aquáticas. pp. 59-83. Maringá: EDUEM. 2003.

CAMPELO, M.J.A.; SIQUEIRA FILHO, J.A. ; COTARELLI, V.M. ; SOUZA, E.B. ; PIMENTA, W.A. ; Pott, J.V. **Macrófitas Aquáticas nas Áreas do Projeto da Integração do Rio São Francisco.** In: José Alves de Siqueira-Filho; Elton Martinez Carvalho Leme.. (Org.). Flora das Caatingas do Rio São Francisco. Flora das Caatingas do Rio São Francisco. Rio de janeiro: Andrea Jakobsson Estúdio Editorial Ltda, v. 1, p. 192-229. 2012.

CAPERS, R.S.; SELSKY, R.; BUGBEE, G.J. The relative importance of local conditions and regional process in structuring aquatic plant communities. **Freshwater Biology** 55, 952-966. 2010.

ESTEVES, F.A. **Fundamentos de Limnologia**. Rio de Janeiro. Interciência/FINEP. 2.ed. Rio de Janeiro. 602p. 1998.

FU, H.; ZHONG, J.; YUAN, G.; NI, L.; XIE, P.; CAO, T. Functional traits composition predict macrophytes community productivity along a water depth gradient in a freshwater lake. **Ecol Evol.** 4(9): 1516–1523. 2014.

GRIMALDO, J.T.; BINI, L.M.; LANDEIRO, V.L.; O'HARE, M.T.; CAFFREY, J.; SPINK, A.; MARTINS, S.V.; KENNEDY, M.P.; MURPHY, K.J. Spatial and environmental drivers of macrophyte diversity and community composition in temperate and tropical calcareous rivers. **Aquatic Botany**. 132: 49-61. 2016.

HAVEL, J.E.; KOVALENKO, K.E.; THOMAZ, S.M.; ALAMFITANO, S.; KATS, L.B. Aquatic invasive species: challenges for the future. **Hydrobiologia**. 750: 147-170. 2015.

HOOPER, D.U.; CHAPIN III, F.S.; EWEL, J.J.; HECTOR, A.; INCHAUSTI, P.; LAVOREL, S.; LAWTON, J.H.; LODGE, D.M.; LOREAU, M.; NAEEM, S.; SCHMID, B.; SETALA, H.; SYMSTAD, A.J.; VANDERMEER, J.; WARDLE, D.A. Effects of biodiversity on ecosystem functioning: A consensus of current knowledge. **Ecol Monogr** 75:3–35. 2005.

IRGANG, B.E.; PEDRALLI, G.; WAECHTER, J.L. Macrófitos aquáticos da Estação Ecológica do Taim, Rio Grande do Sul, Brasil. **Roessléria** 6(1):395-404. 1984.

JANES, H.; KOTTA, J.; PARNOJA, M.; CROWE, T.P.; RINDI, F.; ORAV-KOTTA, H. Functional traits of marine macrophytes predict primary production. *Functional* **Ecology** 31(4): 975-986. 2017.

MELO F.P.L.; ARROYO-RODRIGUEZ, V.; FAHRIG, L.; MARTINEZ-RAMOS, M.; TABARELLI, M. 2013. On the hopefor biodiversity-friendlytropical landscapes. **Trends in Ecology and Evolution** 28: 461–468.

MEYERS, N.; MITTERMEIER, R.A.; MITTERMEIER, C.G.; FONSECA, G.A.B.; KENT, J. Biodiversity hotspots for conservation priorities. **Nature** 403:853–858. 2000.

MICHELAN, T.S.; THOMAZ, S.M.; MORMUL, R.P.; CARVALHO, P. Effects of na exotic invasive macrophyte (tropical signalgrass) on native plant community composition, species richness and functional diversity. **Freshwater Biology** 55, 1315-1326. 2010.

PEDRALLI, G. Macrófitos aquáticos: técnicas e métodos de estudos. **Estudos de Biologia** 26: 5-2. 1990.

PETCHEY, O.L. & GASTON, K.J. Functional diversity: back to basics and looking forward. **Ecol. Lett. Jun**;9(6):741-58. 2006.

PITELLI, R.L.C.M., TOFFANELI, C.M., VIEIRA, E.A., PITELLI, R.A., VELINI, E.D. Dinâmica da comunidade de macrófitas aquáticas no reservatório de Santana, RJ. Viçosa. **Planta daninha**, v. 26, p. 473-480. 2008.

POMPÊO, M.L.M.; MOSCHINI-CARLOS, V. **Macrófitas aquáticas e perifíton: aspectos ecológicos e metodológicos.** São Carlos: RiMa Editora. 134p

POTT, V.J; POTT, A. 2000. **Plantas aquáticas do Pantanal.** Brasília: EMBRAPA. 353p. 2003.

RAUNKIAER, C. **The life forms of plants and statistical plant geography.** Oxford: Claderon Press. 632p. 1934.

THOMAZ, S.M.; BINI, L.M. **Análise crítica dos estudos sobre macrófitas aquáticas desenvolvidos no Brasil.** In: Thomaz, S.M. & Bini, L.M. (eds.). Ecologia e manejo de macrófitas aquáticas. pp. 19-38, Maringá: Eduem. 2003.

CAPÍTULO I

Check-list of aquatic macrophytes of Guaraguaçu River, Brazil, reveals a target for conservation in the Atlantic Rainforest

[1]Formatado segundo as normas do periódico Biota Neotropica.

Check-list of aquatic macrophytes of Guaraguaçu River, Brazil, reveals a target for conservation in the Atlantic Rainforest

Elielton Silva Araújo[1] & André Andrian Padial[1*]

[1]Laboratório de Análise e Síntese em Biodiversidade, Departamento de Botânica, Programa de Pós-graduação em Ecologia e Conservação, Setor de Ciências Biológicas, Universidade Federal do Paraná, Curitiba-PR, Brazil

[*]Corresponding author: André Andrian Padial (aapadial@gmail.com). Present address: Avenida Coronel Francisco H. dos Santos, 100, Caixa Postal: 19031, Centro Politécnico, Curitiba, Paraná, Brazil.

ABSTRACT: Aquatic macrophytes refer to a biological group ranging from macroalgae to angiosperms. This group presents great ecological relevance, being considered important structural components for aquatic biota. This study aimed to create a checklist of the aquatic macrophytes species occurring in the Guaraguaçu River. The species collected from March 2016 to October 2017 were herborized, identified and incorporated to the collection of the Herbarium of the Federal University of Paraná (UPCB). A total of 47 species were registered, corresponding to 37 genera and 28 botanical families, with Cyperaceae and Poaceae being the most representative. In addition, it was registered the occurrence of the exotic invasive species such as *Urochloa arrecta* (Hack. ex T.Durand & Schinz) Morrone & Zuloaga and species with restricted distribution such a *Apalanthe granatensis* (Bonpl.) Planch. The inventory made here shows a significant richness of aquatic macrophytes species in the Guaraguacu River and may contribute to the creation of public policies, once this river represents a central site for biological conservation efforts.
Keywords: floristic composition, aquatic plants, Paraná coastal basin.

INTRODUCTION

The Neotropical region has the highest water availability and number of aquatic ecosystems in the world (Wetzel 2001), which stand out for their high ecological, social and economic value (Pott & Pott 2000, Pompêo 2008). Brazil, in particular, is privileged with such natural resources, presenting complex water bodies with quite varied characteristics (Bove et al. 2003) that allow high biodiversity. However, Brazilian ecosystems have been altered for a long time due to anthropogenic actions such as dam constructions, fishing activities, destruction of riparian forests, as well as the introduction of non-native species (Agostinho et al. 2005, Pelicice et al. 2014, Siqueira-Filho 2012, Vitule et al. 2014, Vitule et al. 2015, Lee et al. 2016).

The aquatic macrophytes form an ecological group considered an important structural component of water bodies (França et al. 2010, Campelo et al. 2013). They present a great variety of ecological functions and requeirements (Pedrali 1990). Indeed, aquatic biodiversity is usually determined by the colonization and establishment of aquatic plants (Ferreira et al. 2010, O'Hare et al. 2017, Wolters et al. 2018).

The richness, composition and structure of aquatic macrophyte communities are, at least partially, determined by environmental gradients. Abiotic characteristics of the water and the variation of the hydrological regime are shown to be important variables shaping aquatic vegetation and filtering organisms more adjusted to the environmental requirements (Sobral-Leite et al. 2010, Meyer & Franceschinelli 2011, Fernándes-Aláez et al. 2016). As a consequence, floristic and ecological studies become key contributions to understand patterns and processes of aquatic communities, given they increase the knowledge about the geographic distribution of species and the relationship between biotic and abiotic factors (Thoma\ & Bini 2003, Pompêo & Moschini-Carlos 2003).

In the south region of Brazil, floristic studies of the aquatic biota are concentrated in the upper Paraná River (Kita & Souza 2000, Ferreira et al. 2011), in the Itaipu Reservoir (Bini et al. 1999, Thomaz et al. 2003) and in several aquatic ecosystems of the Rio Grande do Sul State (Oliveira et al. 1988, Gastal & Irgang 1997, Lisboa & Gastal 2003). There is a clear gap, in other rivers and reservoirs of the region. The Guaraguaçu River is among those with no formal floristic inventory. This river is the largest river of the coastal basin of Paraná State, South Brazil. It is located within the limits of the Guaratuba Environmental Protection Area (APA Guaratuba), and part of its course is also within the limits of the Guaraguaçu River Ecological Station (Slovenski 2000), in the ecoregion called Lagamar (i.e. the estuarine complex in the most preserved region of Atlantic Forest biome, Souza & Oliveira 2016). Therefore, this is a critical ecosystem for aquatic conservation. The Guaraguaçu River water course is affected by tidal regime, the most part of its extension is composed by freshwaters. This is a rare condition in water bodies of LAGAMAR.

Although the Guaraguaçu River presents great ecological and socioeconomic importance for the region where it is inserted, there is a large gap with respect to studies regarding conservation efforts. The present study carries out the first formal checklist of aquatic macrophytes of the Guaraguaçu river, with the purpose of contributing with information about regional biodiversity, as well as generating important data to be used in public policies.

MATERIAL AND METHODS

Study site

The checklist was entirely made in the Guaraguaçu River (25°40'19.95''S, 48°30'47.20''O), which is formed by the confluence of streams from Serra da Prata (Saint Hilaire-Lange National Park) and flows the Paranaguá Bay, an environment of high biological importance that suffers from great anthropogenic impacts such as overfishing (Lana et al. 2001) and introduction of exotic species (Vitule et al. 2006), in addition to being inserted into a major port area (Caires et al, 2007, Contente et al. 2011) (Figure 1 in Supplementary Material).

The river is about 60 km long and presents a well-defined longitudinal gradient from the headwaters to the river mouth. In general it is characterized by dark waters with high levels of humic compounds. In the upstream region, a junction of small streams from the submontane region of Serra da Prata can be observed. After this area, the river presents its most navigable stretch, approximately 30 m wide, and a good conservation status. It is a large "caixetal", a unique and rare region with large occupation of *Tabebuia cassinoides* (Lam.) DC, already listed as endangered in 1997 IUCN red list (IUCN 1997) and characterized by the occurrence of many species typical of riparian vegetation, high water transparency, low tidal influence and low abundance of invasive grasses.

In the intermediate region, there are two rectified channels that are being used as a water catchment system for public supply, as well as for the reception of effluents from bathhouses, a sanitary landfill, and large human occupation in the river margins. The intermediate region can therefore be considered the most impacted by anthropogenic stressors, reflecting directly on the species composition of the aquatic plant community, thereby causing a typical riparian vegetation to be replaced by species considered potentially invasive, with high colonization and establishment capacities, such as *U. arrecta* and *E. crassipes* (even if this last species is native, it can develop to an invasive status, see also Schultz & Dibble 2012, Michelan et al. 2013, Pavão et al. 2017). Downstream of this place with greater human influence, the river enters the Guaraguaçu River Ecological Station, proceeding to the mangrove region, with many halophytic species and where the occurrence of freshwater aquatic macrophytes ends. It is important to point out that the river has a strong tidal influence, presenting a reflux of water in the lowlands. Even so, freshwater is predominant in most part of the river (Silva 2008).

Data collection

The botanical material was collected in four different periods between March 2016 and October 2017. The survey of the floristic composition of aquatic macrophytes followed Pedralli (1990), which presents information on collection and herborization methods, in addition to ecological data, as life forms.

The aquatic environment was sampled with a boat maintained at low speed while the river banks were surveyed by walks, known as walk collection method, following Mormul et al. (2010). The collected material was forwarded for the assembly of exsiccates, identified and later deposited in the scientific collection of the UPCB. The identification of the taxa was carried out through a comparison of the collected material, along with the aid of specialized bibliography and expert consultation. The classification of phanerogamic botanical families was based on Souza and Lorenzi (2008) and APG III (2009), while the classification of pteridophytes followed Smith et al. (2006).

RESULTS AND DISCUSSION

A total of 47 species belonging to 37 genera and 28 botanical families have been recorded (Table 1 in Supplementary Material). It can be considered a significant richness when compared to other studies carried out in the south region of Brazil, such as Rocha and Martins (2011), which collected 54 species in the municipality of Ponta Grossa (PR) through 10 samplings, and Alves et al. (2011), which registered 63 taxa in the Environmental Protection Area (APA) of the Coastal Environment (SC). Even when compared to intensive inventories made in Paraná State, Guaraguaçu River have a substantial amount of species. For instance, Ferreira et al. (2011) collected a total of 153 species in the upper Paraná River floodplain by compiling data from several samplings in geographical extension of hundred of kilometers; and Cervi et al. (2009) surveyed 117 taxa in ponds, reservoirs and streams of the city General Carneiro, south of Paraná, after decades of samplings. Indeed, the fact that our list includes a smaller number of species compared to such inventories may be associated with: i) the number of samplings, ii) the size of the Guaraguaçu River, iii) the fact that part of this river is affected by saltwater, and iv) and the degree of isolation of this river considering the other major aquatic basins. Indeed, given the major Mountain Chains that surround most Brazilian coastline, estuarine systems have poor connection to the other inland waters. Relatedly, it has been shown that the richness of aquatic macrophytes is associated to the area in different scales and bioclimatic factors (Campelo et al. 2013, Moura-Junior et al. 2015). In addition, it is important to emphasize that this is the first study of the floristic composition in the Guaraguaçu River, in which the sampling effort will be expanded in the coming years.

In general, the most representative family was Cyperaceae (15%, seven species), followed by Poaceae and Onagraceae (8.5%, four species each) and Polygonaceae (6.3%, three species) (Figure 2 in Supplementary Material). Other studies have already demonstrated the remarkable presence of species of Cyperaceae and Poaceae in rivers (Pivari et al, 2011, Campelo et al. 2012) and reservoirs (Ferreira et al. 2011, Moura-Junior et al. 2011, Pott et al. 2011, Sabino et al. 2015). This representation commonly found can be explained by the fact that they are cosmopolitan families with high number of species, which have high dispersal capacity due to the presence of rhizomes and tubers (Souza & Lorenzi 2008). According to Pivari et al. (2011), the striking occurrence of Cyperaceae suggests environmental changes in the aquatic ecosystems and formation of floating islands, possibly related to anthropogenic processes.

The most common biological forms found were amphibians (34%, 16 species) and emergents (32%, 15 species). It is an expected result, similar to that obtained in other studies of aquatic macrophytes in Neotropical regions (Henry-Silva et al. 2010, Mormul et al. 2010, Pivari et al. 2011, Rolon et al. 2011, Araujo et al. 2012). The largest number of amphibian and emergent species may be related to the adaptability to both the aquatic and terrestrial environments, especially to environments subject to pulses of seasonal or daily floods from semidiurnal tides (Bove et al. 2003), as occuring in the Guaraguacu River. In addition, the high number of species of the most representative families (Cyperaceae and Poaceae) is related to the high richness of amphibian and emergent species in tropical aquatic ecosystems (Ribeiro et al. 2011).

In studies of aquatic macrophyte communities, it is essential to discuss the presence of exotic invasive species. In the Guaraguaçu River, the most abundant species is the *U. arrecta*, which has caused serious ecological changes regarding the dynamics of tropical aquatic ecosystems (Carniatto et al. 2013, Fernandes et al. 2013, Michelan et al. 2013), especially due to its high biomass that allows high dispersion and establishment capacities (Michelan et al. 2010, Amorim et al. 2015). Another non-native species recorded in Guaraguaçu River is *Nymphaea caerulea* Savugny. Although several species of the family Nymphaeaceae are native and common in Brazil, the species recorded in Guaraguaçu River is originated in the Nile basin. The occurrence of the two non-native species above mentioned suggest that study and conservation efforts should be concentrated in sites such as the Guaraguaçu River, considered vulnerable to biological invasion (Silva 2007, Vitule et al. 2014).

In addition, the occurrence of the species *Apalanthe granatensis* (Bonpl.) Planch was recorded in several sampling sites of the river. This species is considered rare because it has a restricted geographic distribution (Pott & Pott 2000, Bove et al. 2003, Hall & Gil 2016), in addition to presenting a key role in the aquatic community, for example, by increasing the periphytic microalgae species richness (Fernandes et al. 2016). This is the first record of *A. granatensis* in Paraná State, although it can not be considered a biological invasion given its described ranges. In summary, present study revealed a high richness of aquatic macrophytes in the Guaraguaçu River, demonstrating that despite presenting a high degree of anthropogenic impacts and degree of isolation, it is a central water body for the conservation of aquatic biodiversity.

REFERENCES

AGOSTINHO, A.A., THOMAZ, S.M. & GOMES, L.C. 2005. Conservation of the Biodiversity of Brazil´s Inland Waters. Conservation Biology 19(3): 646-652.

ALVES, J.A.A., TAVARES, A.S. & TREVISAN, R. 2011. Composição e distribuição de macrófitas aquáticas na lagoa da Restinga do Massiambu, Área de Proteção Ambiental Entorno Costeiro, SC. Rodriguésia 62(4): 785-801.

AMORIM, S.R., UMETSU, C.A. & CAMARGO, A.F.M. 2015. Effects of a non-native species of Poaceae on aquatic macrophyte community composition: a comparison with a native species. Journal of Aquatic Plant Management 53: 191-196

APG III. 2009. Angiosperm Phylogeny Group. An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG III. Botanical Journal of the Linnean Society 161: 105-121.

ARAÚJO, E.S. SABINO, J.H.F., COTARELLI, V.M., SIQUEIRA-FILHO, J.A. & CAMPELO, M.J. 2012. Riqueza e diversidade de macrófitas aquáticas em mananciais da Caatinga. Diálogos e Ciência (Online) 10: 229-232.

BINI, L.M., THOMAZ, S.M., MURPHY, K.J. & CAMARGO, A.F.M. 1999. Aquatic macrophyte distribution in relation to water and sediment conditions in the Itaipu Reservoir, Brazil . Hydrobiologia 415: 147–154.

BOVE, C.P., GIL, A.S.B., MOREIRA, C.B. & ANJOS, R.F.B. 2003. Hidrófitas fanerogâmicas de ecossistemas aquáticos temporários da planície costeira do Estado do Rio de Janeiro, Brasil. Acta Botanica Brasilica 17(1): 119-135.

CAMPELO, M.J.A., SIQUEIRA-FILHO, J.Á., COTARELLI, V.M., SOUZA, E.B., PIMENTA, W.A. & POTT, J.V. 2012. Macrófitas Aquáticas nas Áreas do Projeto da Integração do Rio São Francisco; p. 192-229. In: SIQUEIRA-FILHO, J.A. & LEME, E.M.C. (Org.). Flora das Caatingas do Rio São Francisco. Rio de janeiro, 193-229.

CAMPELO, M.J.A., SIQUEIRA-FILHO, J.Á. & COTARELLI, V.M. 2013. Structure Community of Aquatic Macrophytes in Springs of the Semiarid, Northeast Brazil. International Journal of Scientific Knowledge 4: 20-28.

CAIRES, R.A., PICHLER, H.A., SPACH, H.L. & IGNÁCIO, J.M. 2007. Opsanus brasiliensis Rotundo, Spinelli & Zavalla-Camin, 2005 (Teleostei: Batrachoidiformes: Batrachoididae), a junior synonym of Opsanus beta (Goode & Bean, 1880), with notes on its occurrence in the Brazilian coast. Biota Neotropica 7: 135–139

CARNIATTO, N., THOMAZ, S.M., CUNHA, E.R., FUGI, R. & OTA, R.R. 2013. Effects of an invasive alien poaceae on aquatic macrophytes and fish communities in a neotropical reservoir. Biotropica, 45: 747–754.

CERVI, A.C., BONA, C., MOÇO, M.C.C. & VON-LINSINGEN, L. 2009. Macrófitas aquáticas do Município de General Carneiro, Paraná, Brasil. Biota Neotrop. 9(3): 215-222.

CONTENTE, R.F., STEFANONI, M.F. & SPACH, H.L. 2011. Fish assemblage structure in an estuary of the Atlantic Forest biodiversity hotspot (southern Brazil). Ichthyol Res 58: 38–50

FERNANDES, U.L., OLIVEIRA, E.C.C. & LACERDA, S.R. 2016. Role of macrophyte life forms in driving periphytic microalgal assemblages in a Brazilian reservoir. Journal of Limnology 75 (1): 44-51

FERNANDES, L.F.G., TEIXEIRA, M.C. & THOMAZ, S.M. 2013. Diversity and biomass of native macrophytes are negatively related to dominance of an invasive Poaceae in Brazilian sub-tropical streams. Acta Limnologica Brasiliensia 25(2): 202-209.

FERNÁNDEZ-ALÁEZ, A., FERNÁNDEZ-ALÁEZ, M., GARCÍA-CRIADO, F. & GARCÍAN-GIRÓN, J. 2016. Environmental drivers of aquatic macrophyte assemblages in ponds along an altitudinal gradient. Hydrobiologia p: 1-20

FERREIRA, F.A., MORMUL, R.P., PEDRALLI, G., POTT, V.J. & POTT, A. 2010. Estrutura da comunidade de macrófitas aquáticas em três lagoas do Parque Estadual do Rio Doce, Minas Gerais, Brasil. Hoehnea 37: 43–52.

FERREIRA, F.A., MORMUL, R.P., THOMAZ, S.M., POTT, A. & POTT, V.J. 2011. Macrophytes in the upper Paraná river floodplain: checklist and comparison with other large South American wetlands. Revista de Biologia Tropical 59 (2): 541-556.

FRANÇA, F., MELO, E., OLIVEIRA, I.B., REIS, A.T.C., ALVES, G.L. & COSTA, M.F. 2010. Plantas vasculares das áreas alagadas dos Marimbus, Chapada Diamantina, BA, Brasil. Hoehnea 37(4): 719–730.

GASTAL-JR., C.V.S. & IRGANG, B.E. 1997. Levantamento de macrófitas aquáticas do Vale do Rio Pardo, Rio Grande do Sul, Brasil. Iheringia 49: 3-9.

HALL, C.F. & GIL, A.S.B. 2016. Flora das cangas da Serra dos Carajás, Pará, Brasil: Hydrocharitaceae. Rodriguesia 67(5): 1367-1371

HENRY-SILVA, G.G., MOURA, R.S.T. & DANTAS, L.L.O. 2010. Richness and distribution of aquatic macrophytes in Brazilian semi-arid aquatic ecosystems. Acta Limnologica Brasiliensis 22(2): 147-156.

KITA, K.K. & SOUZA, M.C. 2003. Levantamento florístico e fitofisionomia da lagoa Figueira e seu entorno, planície alagável do alto rio Paraná, Porto Rico, Estado do Paraná, Brasil. Acta Scientiarum: Biological Sciences 25(1):145-155.

LANA, P.C., MARONE, E.L., LOPES, L.M. & MACHADO, E.C. 2001. The subtropical estuarine complex of Paranaguá Bay, Brazil. In: Seeliger U, Lacerda LD, Kjerfve BJ (eds) Coastal marine ecosystems of Latin America. Springer, Berlin, p: 131–145

LEE, A.C., PERES, C.A., FEARNSIDE, P.M., SCHNEIDER, M. & ZUANON, J.A.S. 2016. Hydropower and the future of Amazonian biodiversity. Biodivers Conserv 25: 451–466.

LISBOA, F.F. & GASTAL-JR, C.C.S. 2003. Levantamento das macrófitas aquáticas na beira do lago Guaíba no município de Guaíba, RS/Brasil. Caderno de Pesquisa Série Biologia 15(1): 17-27.

LORENZI, H. 2008. Plantas daninhas do Brasil: terrestres, aquáticas, parasitas, tóxicas e medicinais. 4. ed. Nova Odessa: Instituto Plantarum.

MEYER, S.T. & FRANCESCHINELLI, E.V. 2011. A influência de variáveis limnológicas sobre a comunidade de macrófitas aquáticas em rios e lagoas da cadeia do Espinhaço, Minas Gerais, Brasil. Rodriguesia 62(4): 743-758.

MICHELAN, T.S., THOMAZ, S.M., MORMUL, R.P. & CARVALHO, P. 2010 Effects of an exotic invasive macrophyte (tropical signalgrass) on native plant community composition, species richness and functional diversity. Freshwater Biology, 55: 1315–1326.

MICHELAN, T.S., THOMAZ, S.M. & BINI, L.M. 2013. Native Macrophyte Density and Richness Affect the Invasiveness of a Tropical Poaceae Species. Plos One 8 (3): 1-8.

MORMUL, R.P., FERREIRA, F.A., CARVALHO, P., MICHELAN, T.S., SIQUEIRA, M.J. & THOMAZ, S.M. 2010. Aquatic macrophytes in the large, sub-tropical Itaipu Reservoir. Revista de Biologia Tropical 58: 1437-1452.

MOURA-JÚNIOR, E.G., LIMA, L.F., SILVA, S.S.L., PAIVA, R.M.S., FERREIRA, F.A., ZICKEL, C.S. & POTT, A. 2015 Aquatic macrophytes of Northeastern Brazil: Checklist, richness, distribution and life forms. Check List 9(2): 298-312.

MOURA-JÚNIOR, E.G., ABREU, M.C., SEVERI, W. & LIRA, G.A.S.T. 2011. O gradiente rio-barragem do reservatório de Sobradinho afeta a composição florística, riqueza e formas biológicas das macrófitas aquáticas?. Rodriguesia 62: 731-742.

OLIVEIRA, M.L.A.A., NEVES, M.T.M.B., STREHL, T., RAMOS, R.L.R. & BUENO, O.L. 1988 Vegetação de macrófitos aquáticos das nascentes do Rio Gravataí (Banhado Grande e Banhado Chico Lomã), Rio Grande do Sul, Brasil – Levantamento Preliminar. Iheringia. Série Botânica 38: 67-80.

O'HARE, M.T., AGUIAR, F.C., ASAEDA, T., BAKKER, E.S., CHAMBERS, P.A., CLAYTON, J.S., ELGER, A., FERREIRA, T.M., GROSS, E.M., GUNN, I.D.M., GURNELL, A.M., HELLSTEN, S., HOFSTRA, D.E., LI, W., MOHR, S., PUIJALON, S., SZOSZKIEWICZ, K., WILLBY, N.J. & WOOD, K.S. 2017. Plants in aquatic ecosystems: current trends and future directions. Hydrobiologia. 1-11. DOI 10.1007/s10750-017-3190-7

PAVÃO, A.C., SANTOS, A.C.A., BOTTINO, F., BENASSI, R.F. & CALIJURI, M.C. 2017. Richness and distribution of aquatic macrophytes in a subtropical reservoir in São Paulo, Brazil. Acta Limnologica Brasiliensia 29(10): 1-11.

PEDRALLI, G. 1990. Macrófitos aquáticos: técnicas e métodos de estudos. Estudos de Biologia 26: 5-24.

PELICICE, F.M. & AGOSTINHO, A.A. 2009. Fish fauna destruction after the introduction of a non-native predator (Cichla kelberi) in a Neotropical reservoir. Biological Invasions 11: 1789–1801

PELICICE, F.M., VITULE, J.R.S., LIMA, D.P., ORSI, J.M.L. & AGOSTINHO, A.A. 2014. A serious new threat to Brazilian freshwater ecosystems: the naturalization of nonnative fish by decree. Conservation Letters 7: 55–60

PIVARI, M.O., OLIVEIRA, V.B., COSTA, F.M., FERREIRA, R.M. & SALINO, A. 2011. Macrófitas aquáticas do sistema lacustre do Vale do Rio Doce, Minas Gerais, Brasil. Rodriguésia 62 (4): 759-770.

POMPÊO, M.L.M. 2008. Monitoramento e manejo de macrófitas aquáticas. Oecologia Brasiliensis 12: 406–424.

POMPÊO, M.L.M. & MOSCHINI-CARLOS, V. 2003. Macrófitas aquáticas e perifíton: aspectos ecológicos e metodológicos. São Carlos: RiMa Editora. 134p.

POTT, V.J., POTT, A., LIMA, L.C.P., MOREIRA, S.N. & OLIVEIRA, A.K.M. 2011. Aquatic macrophyte diversity of the Pantanal wetland and upper basin. Brazilian Journal of Biology 1: 255-263.

POTT, V.J. & POTT, A. 2000. Plantas aquáticas do Pantanal. Brasília: EMBRAPA. 353p.

RIBEIRO, J.P.N., TAKAO, L.K., MATSUMOTO, R.S., URBANETZ, C. & LIMA, M.I.S. 2011. Plantae, aquatic, amphibian and marginal species, Massaguaçu River Estuary, Caraguatatuba, São Paulo, Brazil. Check List 7(2): 133- 138.

ROCHA, D.C. & MARTINS, D. 2011. Levantamento de plantas daninhas aquáticas no Reservatório de Alagados, Ponta Grossa-Pr. Planta Daninha 29(2): 237-246.

ROLON, A.S., ROCHA, O. & MALTCHIK, L. 2011. Diversidade de macrofitas aquáticas do Parque Nacional da Lagoa do Peixe. Neotropical Biology and Conservation 6: 5-12.

SABINO, J.H.F., ARAUJO, E.S., COTARELLI, V.M., SIQUEIRA-FILHO, J.A. & CAMPELO, M.J.A. 2015. Riqueza, composição florística, estrutura e formas biológicas de macrófitas aquáticas em reservatórios do semiárido nordestino, Brasil. Natureza on line 13(4): 184-194.

SCHULTZ, R. & DIBBLE, E. 2012. Effects of invasive macrophytes on freshwater fish and macroinvertebrate communities: the role of invasive plant traits. Hydrobiologia 684(1): 1-14.

SILVA, F.F.G. 2008. Composição e distribuição da ictiofauna do Rio Guaraguaçu (Paranaguá, Paraná-BR) e biologia alimentar de três espécies. Mestrado em Zoologia, Universidade Federal do Paraná, Curitiba.

SIQUEIRA-FILHO, J.A. 2012. Flora das Caatingas do Rio São Francisco : História natural e conservação. 1. ed. Rio de Janeiro, 552p

SLOVENSKI, A.C. 2000. Aspectos fitossociológicos e pedológicos de três superfícies de agradaçào do rio Guaraguaçu, litoral do Paraná. Dissertação Mestrado em Ciências Florestais. Universidade Federal do Paraná, Curitiba,.

SMITH, A.R., PRYER, K.M., SCHUETTPELZ, E., KORALL, P., SCHNEIDER, H. & WOLF, P.G. 2006. A classification for extant ferns. Taxon 55: 705-731.

SOBRAL-LEITE, M., CAMPELO, M.J.A., SIQUEIRA-FILHO, J.A. & SILVA, S.I. 2010. Checklist das macrófitas vasculares de Pernambuco: Riqueza de espécies, formas biológicas e considerações sobre distribuição. In: ALBUQUERQUE, U.P., MOURA, A.N. & ARAÚJO, E.L. (org.). Biodiversidade, potencial econômico e processos eco-fisiológicos em ecossistemas nordestinos. Recife, Ed. Nupeea, 255-280

SOUZA, V.C. & LORENZI, H. 2008. Botânica Sistemática: Guia ilustrado para identificação das famílias de Angiospermas da flora brasileira, baseado em APG II. 2ª Ed. Nova Odessa, Instituto Plantarum, 704p.

SOUZA, T.A. & OLIVEIRA, R.C. 2016. Alterações ambientais no complexo estuarino-Lagunar de Cananeia-Iguape: a influência do canal artificial do “valo grande”. Boletim de Geografia 34(12): 30-44.

THOMAZ, S.M. & BINI, L.M. 2003. Análise crítica dos estudos sobre macrófitas aquáticas desenvolvidos no Brasil; p: 19-38. In: Thomaz SM, Bini LM (eds.). Ecologia e manejo de macrófitas aquáticas. Maringá: Eduem.

THOMAZ, S.M., SOUZA, D. & BINI, L.M. 2003. Species richness and beta diversity of aquatic macrophyte in a large subtropical reservoir (Itaipu Reservoir, Brazil): the influnce of limnology and morfometry. Hydrobiologia 505: 119-128.

VITULE, J.R.S., AZEVEDO-SANTOS, V.M., DAGA, V.S., LIMA-JUNIOR, D.P., MAGALHÃES, A.L.B., ORSI, M.L., PELICICE, F.M. & AGOSTINHO, A.A. 2015. Brazil's drought: protect biodiversity. Science 347: 1427–1428.

VITULE, J.R.S., UMBRIA, S.C. & ARANHA, J.M.R. 2006. Introduction of the African catfish *Clarias gariepinus* (Burchell, 1822) into Southern Brazil. Biol Invations 8:677-681

VITULE, J.R.S., BORNATOWSKI, H., FREIRE, C.A. & ABILHOA, V. 2014. Extralimital introductions of Salminus brasiliensis (Cuvier, 1816) (Teleostei, Characidae) for sport fishing purposes: a growing challenge for the conservation of biodiversity in neotropical aquatic ecosystems. Biological Invasions Rec 3(4): 291–296.

VITULE, J.R.S., UMBRIA, S.C. & ARANHA, J.M.R. 2006. Introduction of the African catfish Clarias gariepinus (Burchell, 1822) into Southern Brazil. Biol Invations 8: 677–681

WETZEL, R.G. 2001. Limnology. San Diego: Academic Press. 1006 p.

WOLTERS, J.W. VERDONSCHOT, R.C.M., SCHOELYNCK, J., VERDONSCHOT, P.F.M. & MEIRE, P. "in press" The role of macrophyte structural complexity and water flow velocity in determining the epiphytic macroinvertebrate community composition in a lowland stream. Hydrobiologia 806 (1): 157-173.

Supplementary Material

Index

Subtitles:

Figure 1, Geographical location of the Guaraguaçu River, Parana, Brazil, showing location of the pristine “caixetal area”, the mangrove area where water is permanently brackish, and the area of greater anthropogenic impact (the intermediate are between "caixetal" and "mangrove"). Number indicate locations of main sampling sites, although checklist was done after active search of all river. In the intermediate areas, it is also highlighted the rectified channels (RC). The one in the right has a damping ground (DG) and receives great amount of domestic effluents from municipalities; whereas the left RC has a water caption station (WA) from the State Sanitation Company.

Figure 2, Number of species by family of aquatic macrophytes recorded in Guaraguaçu river, Paraná, Brazil, between September 2016 and September 2017 (n=47).

Table 1, Lists of aquatic macrophytes and life forms recorded in Guaraguaçu river, Paraná, Brazil. AM = amphibious; EM = emergent; EP = epiphyte; FF = free floating; FS = free submerged; RF = rooted floating; and RS = rooted submerged.

Figure 1

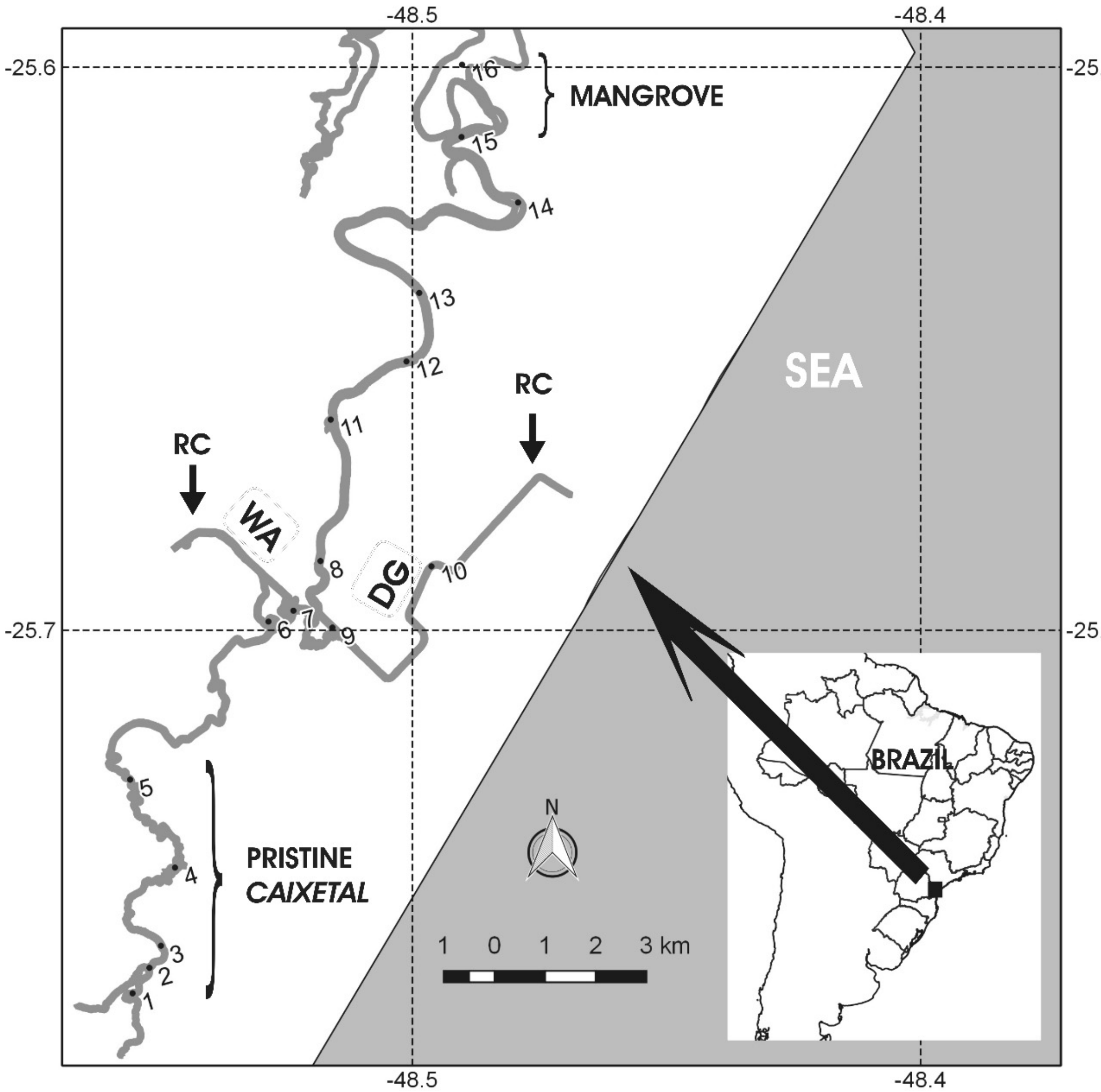
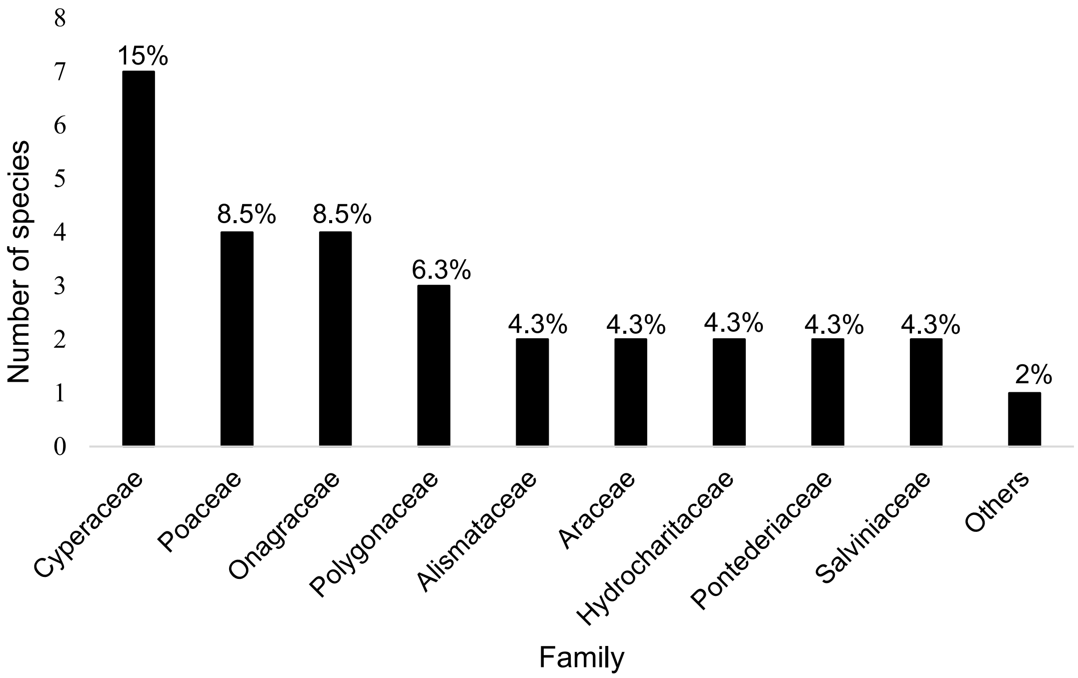

-48.5
-48.4
-25.6
-25.6
MANGROVE
16
15
14
13
12
11
SEA
RC
RC
WA
DG
8
10
7
6
9
-25.7
-25.7
BRAZIL
5
N
4
PRISTINE
CAIXETAL
3
2
1
1 0 1 2 3 km
-48.5
-48.4

Figure 2



Number of species
0
1
2
3
4
5
6
7
8
15%
8.5%
8.5%
6.3%
4.3%
4.3%
4.3%
4.3%
4.3%
2%
Cyperaceae
Poaceae
Onagraceae
Polygonaceae
Alismataceae
Araceae
Hydrocharitaceae
Pontederiaceae
Salviniaceae
Others
Family

Table 1

FAMILY/SPECIES	LIFE FORMS	VOUCHER
ALISMATACEAE		
Echinodorus grandiflorus (Cham. & Schltr.) Micheli	EM	92723
Echinodorus tenellus tenellus (Mart. ex. Roem. & Schult.) Buchenau	AM	87714
AMARANTHACEAE		
Alternanthera philoxeroides (Mart.) Griseb.	AM	92713
AMARYLLIDACEAE		
Crinum americanum L.	EM	92712
ARACEAE		
Lemna valdiviana Phil.	FF	92716
Pistia stratiotes L.	FF	58254
ARALIACEAE		
Hydrocotyle leucocephala Cham. & Schltdl.	FF	92717
ASTERACEAE		
Wedelia padulosa DC.	AM	92721
BEGONIACEAE		
Begonia fischeri Schrank	AM	92711
COMMELINACEAE		
Commelina nudiflora L.	AM	87705
CONVOLVULACEAE		
Ipomoea carnea Jacq.	AM	92598
CYPERACEAE		
Cyperus giganteus Vahl	EM	87708
Cyperus pohlii (Nees) Steud.	AM	92710
Eleocharis geniculata (L.) Roem. & Schult.	AM	92730
Eleocharis interstincta (Vahl) Roem. & Schult.	EM	92704
Eleocharis tenuissima Boeckeler	EM	92724

Oxycaryum cubense (Poepp. & Kunth) Lye	EP	87707
Rhynchospora corymbosa (L.) Britton	E	92709
HALORAGACEAE		
Myriophyllum aquaticum (Vell.) Verdc.	RS	87712
HYDROCHARITACEAE		
Apalanthe granatensis (Bonpl.) Planch.	RS	92731
Egeria densa Planch.	RS	92600
JUNCACEAE		
Juncus brasiliensis Breistr.	AM	87706
LENTIBULARIACEAE		
Utricularia gibba L.	FS	92596
LYCOPODIACEAE		
Palhinhaea cernua (L.) Franco & Vasc.	AM	87704
MALVACEAE		
Talipariti pernambucense (Arruda) Bovini	AM	92705
MELASTOMATACEAE		
Tibouchina trichopoda (DC.) Baill.	AM	92301
NYMPHAEACEAE		
Nymphaea caerulea Savugny	RF	92595
ONAGRACEAE		
Ludwigia grandiflora (Michx.) Greuter & Burdet	EM	92597
Ludwigia erecta (L.) H.Hara	AM	92732
Ludwigia helminthorrhiza (Mart.) H.Hara	FF	92733
Ludwigia octovalvis (Jacq.) P.H.Raven	EM	92722
ORCHIDACEAE		
Habenaria repens Nutt.	EM	92729
POACEAE		
Hymenachne amplexicaulis (Rudge) Nees	EM	92702
Panicum aquaticum Poir.	EM	92715

Panicum schwackeanum Mez	EM	92707
Urochloa arrecta (Hack. ex T.Durand & Schinz) Morrone & Zuloaga	EM	87713
POLYGONACEAE		
Polygonum hidropiperoides Michx.	EM	92720
Polygonum punctatum Elliott	AM	92714
Polygonum stelligerum Cham.	AM	92701
PONTEDERIACEAE		
Eichhornia azurea (Sw.) Kunth	FF	92599
Eichhornia crassipes (Mart.) Solms	FF	52526
POTAMOGETONACEAE		
Potamogeton illinoensis Morong	RF	91220
PTERIDACEAE		
Ceratopteris thalictroides (L.)Brongn.	AM	87703
RICCIACEAE		
Ricciocarpos natans (L.) Corda	FF	92725
SALVINIACEAE		
Azolla caroliniana Willd.	FF	58257
Salvinia biloba Raddi	FF	87715
TYPHACEAE		
Typha dominguensis Pers.	EM	92726

CAPÍTULO II

Environmental degradation and salinity control taxonomic and functional macrophyte distribution in a Neotropical coastal river

[1] Formatado nas normas do periódico Aquatic Sciences

Environmental degradation and salinity control taxonomic and functional macrophyte distribution in a Neotropical coastal river

Elielton S. Araújo[1] & André Andrian Padial[1*]

[1]Laboratório de Análise e Síntese em Biodiversidade, Departamento de Botânica, Programa de Pós-graduação em Ecologia e Conservação, Setor de Ciências Biológicas, Universidade Federal do, Curitiba-PR, Brazil

[*]Corresponding author: André Andrian Padial (aapadial@gmail.com), (+55 41 33611790) Present address: Avenida Coronel Francisco H. dos Santos, 100, Caixa Postal: 19031, Centro Politécnico, Curitiba, Paraná, Brazil.

ABSTRACT: A better understanding of community assembly is achieved when the response of the plant community in continental aquatic ecosystems is made using both the taxonomic identity and the functional traits of the individuals. We described the spatial and temporal variation of the taxonomic and functional diversity and composition of the community of aquatic macrophytes in the Guaraguaçu River, a subtropical tidal river in southern Brazil. Macrophyte beds were sampled semiannually during two consecutive years. Modules of each species in each macrophyte bed recorded were sampled for eleven functional traits related to the growth, establishment, and fitness. There was always spatial variation of the diversity and community composition. Temporal variation was only observed in fuctional community composition. There was no clear distinction between areas of high and low anthropogenic impact considering diversity metrics; but such areas highly differ considering community composition. There was a positive relationship between species richness and functional diversity indexes, but no evidence for functional redundancy. Intraspecific trait variability, which can be attributed to the phenotypic plasticity of the species, mostly contributed to the functional richness. We emphasized the importance of addressing intraspecific variability in studies of functional ecology in order to better understand the mechanisms of community assembly. We advocate that anthropogenic impacts are central to macrophyte community assembly. Finally, we suggest that salinity is an important environmental filter of macrophytes in coastal rivers such as the Guaraguaçu.

Keywords: aquatic macrophytes, functional diversity, spatio-temporal variation, Paraná coast.

INTRODUCTION

In fluvial systems, spatial changes in communities can be predicted by The River Continuum Concept (Ward and Stanford 1983): from small to large-scale streams, it is expected an increasing gradient of biodiversity and a predictable change in species composition. However, landscape features, along with anthropogenic impact on the surrounding environment, are the main determinants for the most part of the river extension (Boechat et al. 2013; Queiroz and Rocha, 2010; Rodrigues et al. 2010).

Aquatic macrophytes represent a dynamic ecological group whose species composition and biodiversity change rapidly due to environmental variations, such as those related to seasonality and hydrological variation (Bornette and Puijalon 2011; Ceschin et al. 2018; Fritz et al. 2017; Maltchik et al. 2007). Considering the community of aquatic macrophytes in tidal rivers, a change in floristic composition along the river should also occur through the environmental filter of salinity (Guo and Pennings 2012; Nunes and Camargo 2016). Therefore, in addition to species varying spatially, a substantial temporal variation is also common (Fu et al. 2014; Li et al. 2017; Thomaz et al. 2009a, b). However, the identification of the main source of variation contributing to the total diversity of aquatic macrophytes is context-dependent, with no definitive conclusion for all ecosystems. However, the determination of this main source of variation may support conservation strategies by indicating which source of heterogeneity should be promoted to result in greater diversity over time and space (Socolar et al. 2016).

In addition, diversity has multiple facets, and functional diversity does contribute to a better understanding of the effects of communities on the stability and functioning of ecosystems (Cadotte 2011; Cadotte et al. 2011; Flynn et al. 2011; Fornara and Tilman 2008; Petchey and Gaston 2006). Also, describing patterns in functional composition may better elucidate how ecological filters determine the spatial and temporal changes of communities (Fu et al. 2014).

Functional diversity is estimated by measuring traits of individuals. Such traits are morphological and ecological features of individuals that relates to how they affect and are affected by the functioning of ecosystems, such as productivity, stability, and cycling of nutrients (Capers et al. 2010; Cardinale et al. 2012; Tilman 2001). In this sense, relating taxonomic and functional diversity may reveal how biodiversity affect the functioning of ecosystems. For instance, one may conclude that if functional diversity increases indefinitely with species richness, the extinction of any species represents a functional loss for the community. On the other hand, if the addition of species does not cause an increase in functional diversity, the community is composed of functionally redundant species that guarantee the long-term stability of that ecosystem. In cases like this, the functioning of ecosystems should not be affected by the loss of species, as predicted by the insurance hypothesis (Loreau et al. 2002; Naeem 1998; Naeem and Li 1997).

Functional traits vary among species of macrophytes and, within each species, between individuals. Since the growth habit of many macrophyte species is clonal and branched, with a single individual giving rise to an extensive vegetal bank, intraspecific variation in a macrophyte bed can be measured at modules (defined as the minor repeating portion containing a root, stem, and leaves, see Pérez-Harguindeguy et al. 2013). In this sense, it is also important to evaluate how much of the functional diversity is composed by intraspecific trait variation (see also de Bello et al. 2011; Carlucci et al. 2015; Cianciaruso et al. 2009; Spasojevic et al. 2016).

The main goal of this study was to describe the spatial and temporal variation of the diversity and community composition, both taxonomic and functional, of aquatic macrophytes in the Guaraguaçu River, a subtropical tidal river in southern Brazil – in the most preserved remnants of the Atlantic Forest hotspot (Myers et al. 2000). We investigated the main scale of variation by comparing the partition between components of spatial and temporal variation with a null model. Finally, the relationship between taxonomic and functional diversity, as well as the contribution of intra and interspecific variation to the functional diversity of aquatic macrophytes were also evaluated.

MATERIALS AND METHODS

Study area

The study was carried out in the Guaraguaçu River (Figure 1), a tropical river with strong tidal influence and conspicuous longitudinal variation, forming differentiated microhabitats (Lana et al. 2001).

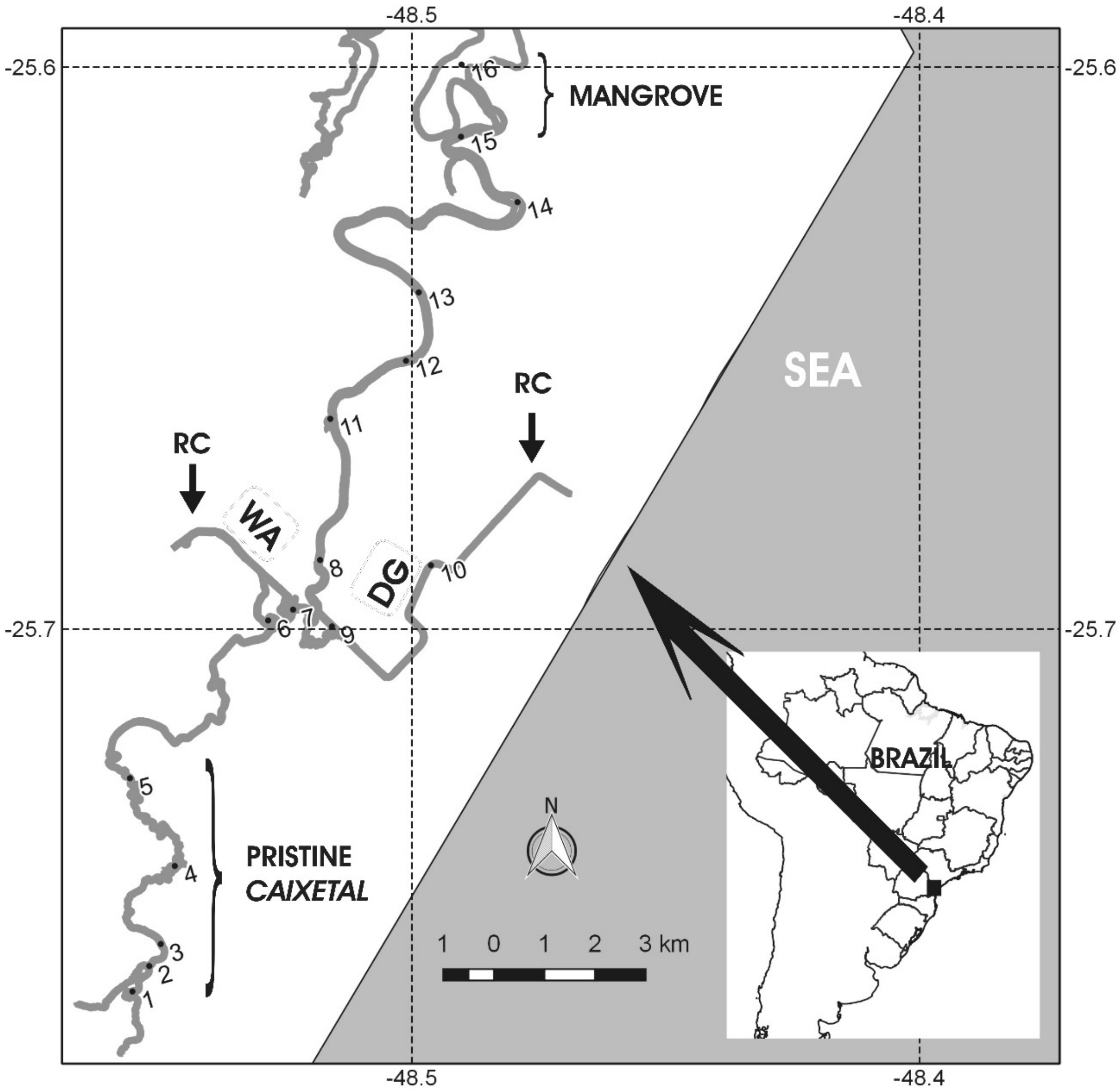


Figure 1: Geographical location of the macrophyte beds sampled in Guaraguaçu River, Parana, Brazil, showing also: location of the pristine "caixetal area", the mangrove area where water is permanently brackish, and the area of greater anthropogenic impact (the intermediate are between "caixetal" and "mangrove"). In the intermediate areas, it is also highlighted the rectified channels (RC). The one in the right has a damping ground (DG) and receives great amount of domestic effluents from municipalities; whereas the left RC has a water caption station (WA) from the State Sanitation Company.

The Guaraguaçu River is the largest river in the coastal basin of Paraná State and is located in a priority region for biodiversity conservation in Brazil. The colonization of macrophytes is intense. It is also clear that environmental variation occur along the river, with brackish waters reported at the downstream, strong degradation in water quality given anthropogenic disturbances in its intermediate stretch (where there is only freshwaters), and low degradation in the upstream near-pristine region known as "caixetal" – a unique ecosystem characterized by the high abundance of the amphibian tree *Tabebuia cassinoides* Lam. (DC.) (Bignoniaceae) and with high concentration of humic and fulvic acid compounds (Silva 2008; unpublished data; see location in Figure 1).

In the intermediate region, there are two rectified channels that are being used as a water catchment system for public supply, as well as for the reception of effluents from bathhouses, a sanitary landfill, and large human occupation in the river margins (see locations in Figure 1). This region can be considered the most impacted by anthropogenic stressors, reflecting directly on the species composition of the aquatic community with macrophyte species considered potentially invasive, such as *Urochloa arrecta* (Hack. ex T.Durand & Schinz) Morrone & Zuloaga and *Eicchornia crassipes* (Mart.) Solms (even if this last species is native, it can develop to an invasive status, see Michelan et al. 2013; Pavão et al. 2017; Schultz and Dibble 2012). In addition, there are records of several non-native fish and invertebrate species, such as *Clarias gariepinus* (Burchell, 1822), *Ictalurus punctatus* (Rafinesque, 1818), *Salminus brasiliensis* (Cuvier, 1816) (see Vitule 2007; Vitule et al. 2006), tilapias and Malaysian giant shrimp (in preparation).

As a tidal river in coastal floodplain, the water flow is inverted twice a day in most of its extension, which causes level fluctuation up to nearly 2 meters (personal observation). Finally, seasonality is also common in this region, considering mainly temperature and rainfall (dry season in winter, and wet season in summer, although precipitation occurs during all the year reaching nearly 2000 mm, see Camargo and Harari 2003). Therefore, the expectation of high temporal and spatial variation in aquatic macrophytes is justified.

Data collection

To carry out the work, 16 macrophyte beds were selected and georeferenced along the navigable stretch of the river, which is 30 km long (Figure 1). The taxonomic composition was evaluated with seasonal field trips (March/October) for two consecutive years (2016/2017), following the conventional method of collection and herborization of aquatic macrophytes (Pedrali 1990) in all selected macrophyte beds. The species in the reproductive stage were collected, herborized, and indexed in the scientific collection of the Botany Department Herbarium of the Federal University of Paraná (UPCB-UFPR).

The extension of macrophyte beds were at least 50 m. All species were recorded within 50 m of each macrophyte bed, following an adaptation for aquatic macrophytes of the RAPELD protocol (see Magnusson et al. 2005). Macrophytes beds distance from each other was variable, but was naver lower than 1 km (Figure 1). Considering the different levels of anthropogenic impact and environmental features along the river, we identified three different categories: low anthropogenic impact (macrophyte beds 1-5), high anthropogenic impact (macrophyte beds 6-14) and mangrove area (macrophyte beds 15-16) (Figure 1). The first is located upstream and is characterized by near-pristine areas with few human interference, with no salinity and with high concentration of humic- and fulvic-acid compounds given decomposition of leafs and steams of vegetation from the pristine mountain areas of Atlantic Forest where the river spring is located. The second is at the intermediate stretch of the river, where there is intense human occupation, and where ditches were artificially constructed to both water catchment and (rather paradoxically) drain domestic effluents from municipalities nearby. There is also a dumping ground in one margin of a ditch that certainly contributes to water pollution (Figure 1). The third is a mangrove area were colonization of macrophytes ceases and with permanently brackish waters (macrophyte beds 15 and 16 in Figure 1). This is a relatively well preserved area with two important conservation units (“Estação Ecológica do Rio Guaraguaçu” and “Reserva Estadual do Palmito”) in some extension of the left margin of the river. Even with these clear differences in abiotic features, such classification is also highly supported by the mean relative abundance (across sampling periods) of the non-native and invasive species *U. arrecta* (Figure 2).

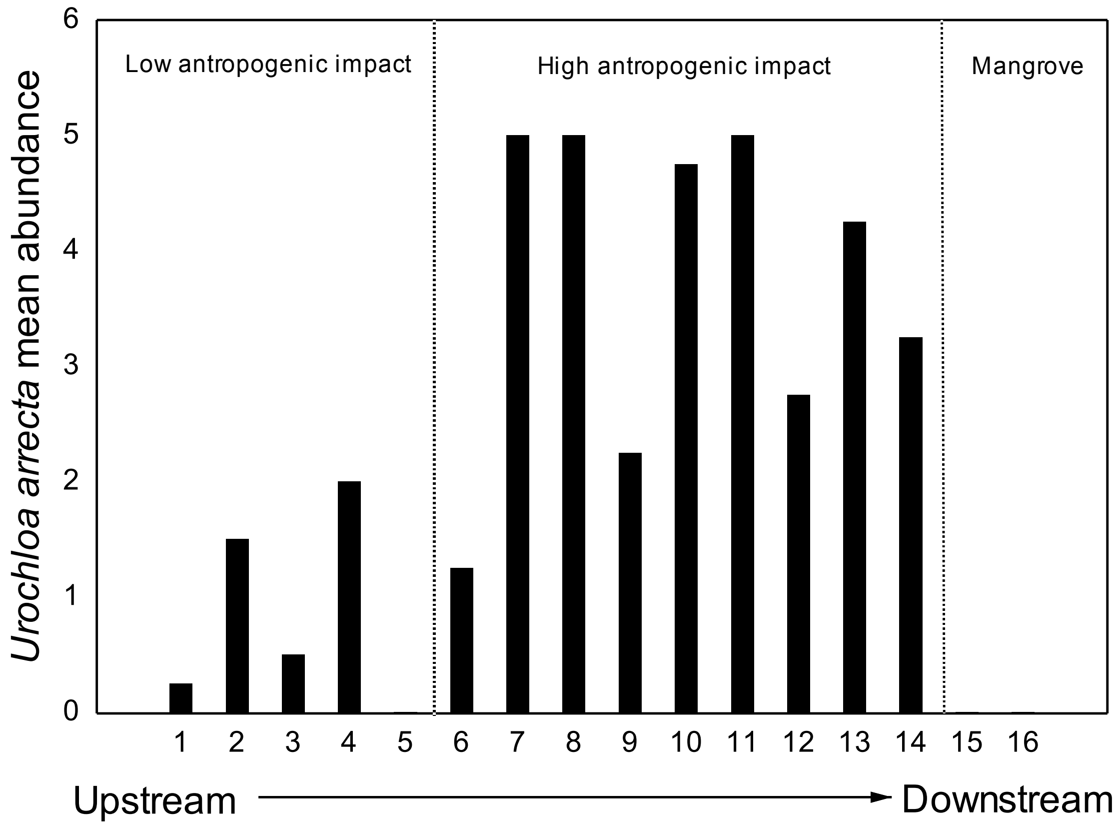


Figure 2: Mean relative abundance (across sampling periods) of the non-native invasive *Urochloa arrecta* (Hack. ex T.Durand & Schinz) Morrone & Zuloaga in each macrophyte bed. Relative abundances were estimated using Braun-Blanquet classes (see methods) considering the occupancy of the species in the 50 m extension of each macrophyte bed.

For each species recorded in each macrophyte bed, we estimated abundance by using Braun-Blanquet abundance classes considering the occupancy of each species in the 50 m extension of macrophyte beds (0 = 0%; 1 = less than 5%; 2 = 5-25%; 3 = 25-50%; 4 = 50-75%; 5 = greater than 75% of occupancy). Considering that aquatic macrophytes are modular organisms, three modules of each species recorded were selected in each macrophyte bed to measure the following functional traits: root length (cm); leaf length (cm), leaf width (cm) and leaf area (cm^2), petiole length (cm), stem width (cm), herbivory degree (same abovementioned Braun-Blanquet classes considering the percentage of leaf area covered by herbivory). Also, we consulted specialized bibliographies (APG 2009; Moura-Junior et al. 2015; Pott and Pott 2000) to determine, for each species: leaf pubescence (pubescent or glabrous), flowering (seasonal or annual), and life form (emergent, rooted floating, free floating, rooted submerged, free submerged, amphibian, epiphyte). Such functional traits are commonly used in studies of aquatic macrophytes and provide important information on biological responses to environmental variation, as they may affect critical stages of colonization and establishment, as well as the adaptive value of species (Cavalli, Baattrup-Pedersen and Riis 2014; Violle et al. 2007).

Data analysis

In order to describe the diversity and community composition as dependent of the macrophyte bed and period evaluated; matrices of species composition and functional traits were organized (see metadata in Supplementary Material, complete matrices are available contacting aapadial@gmail.com). For each macrophyte bed in each period, we calculated the species richness, the index of Shannon-Wiener, the Pielou's equity, as well as the following functional diversity indexes: functional richness (FRic), functional divergence (FDiv), functional dispersion (FDis), and Rao's quadratic entropy (RaoQ) (Laliberté and Legendre 2010). We chose such diversity indexes given they are complementary considering the facet of biodiversity evaluated (see Magurran 2013 for taxonomic indexes; and Mouchet et al. 2010 for functional diversity indexes). Functional indexes were calculated in two ways: i) considering the average trait values for all modules sampled for each species (thus accounting only for interspecific variation in traits), and ii) considering the average trait values for each species in a certain macrophyte bed and sampling period (using averages for the three modules and, thus, accounting for inter and intraspecific variations in traits).

We tested differences among macrophyte beds (i.e. spatial variation) using the four samplings periods as replicates; and differences among sampling periods (i.e. temporal variation) using the 16 macrophyte beds as replicates. For that, we used Analysis of Variance (ANOVA). We dig further in comparing spatial and temporal variation in species richness by calculating the relative contribution of diversity within macrophyte beds, variation among macrophyte beds, and variation among periods to the gamma diversity was evaluated using an additive diversity partitioning and with a null model analysis (Crist et al. 2003).

PCoA ordinations were performed with the Bray-Curtis dissimilarities in abundance of the species; and Gower's dissimilarities of community-weighted mean (CWM) trait values (Lavorel et al. 2008) in order to verify the structure of the taxonomic and functional composition by macrophyte bed in each period. We used Gower's dissimilarity index given it allows using different types of functional traits (continuous and categorical variables), assigning equal weights for each trait (Villéger, Mason & Mouillot 2008). CWM matrix of functional composition was calculated using only the averaged traits of modules for each macrophyte bed in each period (thus accounting for inter and intraspecific trait variations). We tested for differences among macrophyte beds or sampling periods in community composition using Permutational Multivariate Analysis of Variance (PERMANOVA; Anderson 2001).

We also formally investigated spatial autocorrelation in the taxonomic and functional community composition by Mantel correlation of (in each period) the matrix of the geographic distances among all macrophyte beds and both: (i) the Bray-Curtis dissimilarities of species abundances; and ii) the Gower's dissimilarities of CWM.

We then explored the contribution of inter and intraspecific variation in traits by dividing the FRic calculated considering only interspecific trait variability by FRic considering also intraspecific trait variability. We calculated a mean of such ratio for each macrophyte bed in each period. Also, we tested for differences among interspecific FRic and intraspecific FRic using a paired *t*-test. In this case, intraspecific FRic was considered as the total FRic minus interspecific FRic. We used only FRic for this analysis given we aimed only to explore if intraspecific trait variability significantly increases the size of trait ranges (that can be estimated considering convex hull volume calculated by FRic, see Villéger et al. 2008); and not to explore other functional diversity facets that are also dependent on the relative abundance of the species in a community (FDiv, FDis and RaoQ, see Mouchet et al. 2010).

Finally, the relationship between species richness and all functional diversity indexes was tested with the Michaelis-Menten saturation curve ($y = a*x/(b+x)$). The analyses were performed using the R software, version 3.4.3 (R Core Team 2017) and the Statistica software version 7.0 (StatSoft 2005).

RESULTS

All facets of diversity and composition of aquatic macrophytes varied between macrophyte beds, but not between sampling periods (except for functional community composition, Table 1).

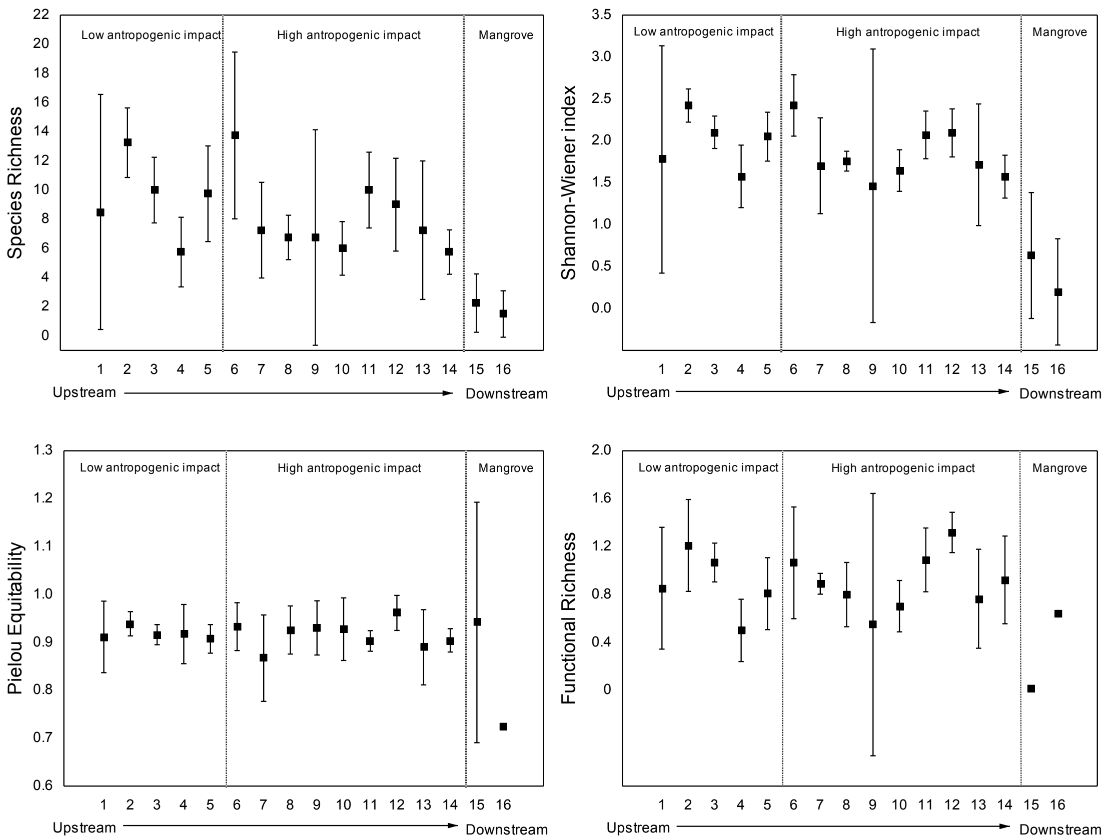
Table 1: Diversity and taxonomic and functional composition of aquatic macrophytes in the Guaraguaçu River depending on macrophyte bed and period evaluated.

	Macrophyte beds		**Periods**	
	F	*P*	F	*P*
Species Richness	**7.311**	**< 0.001**	7.311	0.801
Shannon-Wiener index	**7.827**	**< 0.001**	0.666	0.576
Pielou Equitability	**2.850**	**0.003**	1.371	0.261
Functional Richness	**5.011**	**<0.001**	1.997	0.896

Functional Divergence (FDiv)	**3.673**	**<0.001**	0.763	0.520
Funcional Dispersion (FDis)	**7.147**	**<0.001**	1.213	0.313
Rao Q Entropy (RaoQ)	**8.285**	**<0.001**	1.005	0.397
Taxonomic Composition	**6.347***	**0.001**	1.366*	0.149
Functional Composition	**1.426***	**<0.001**	**1.552***	**0.003**

*A Pseudo-F is calculated according to PERMANOVA approach, see Anderson (2001).

In general, the area further downstream of the river, where the mangrove is located, has the lowest taxonomic and functional diversity (Figure 3). There is no clear distinction from taxonomic and functional diversity between areas with higher and lower anthropogenic impact (Figure 3), but taxonomic and functional composition indeed varied among categorized areas (Figure 4). Considering temporal variation in community composition, it was mainly observed between October of 2017 and April of 2016, and thus, did not show clear seasonal changes (see Figure S1 in Supplementary Information).



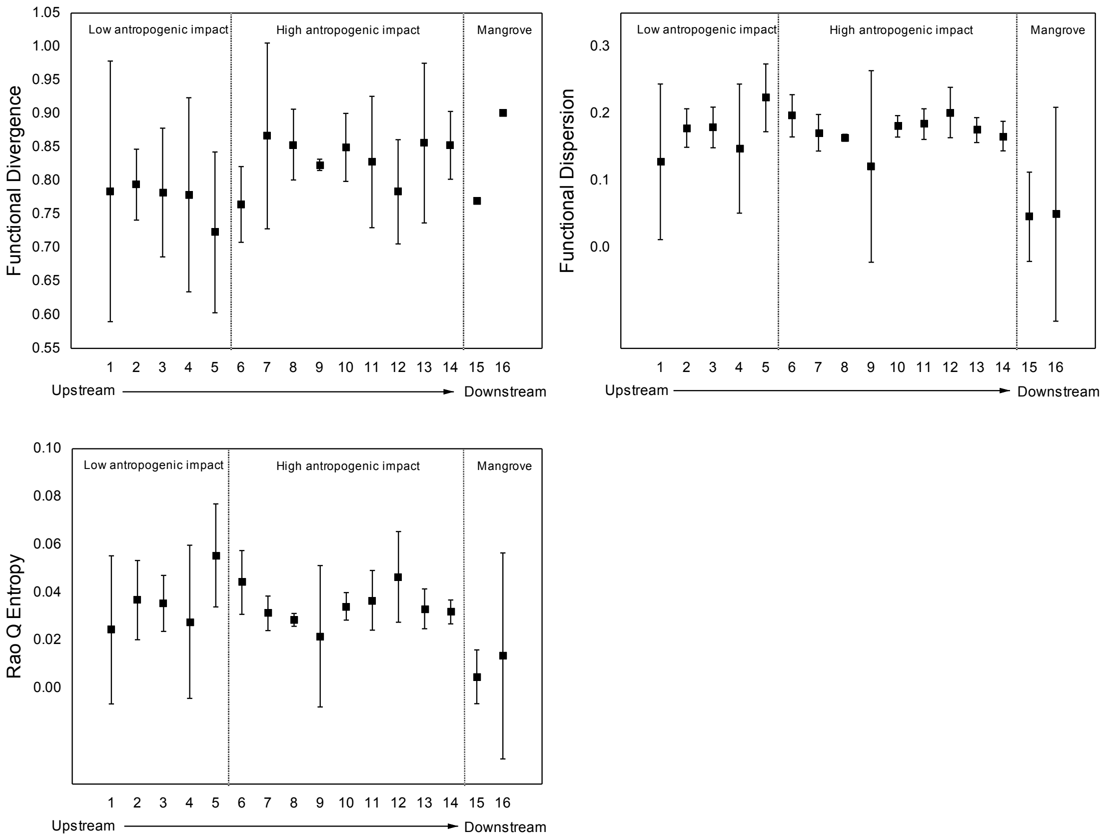


Figure 3: Mean (± SD, across sampling periods) taxonomic and functional diversity indexes in each macrophyte bed from upstream to downstream in the different areas categorized according to anthropogenic impact and presence of mangrove (see methods).

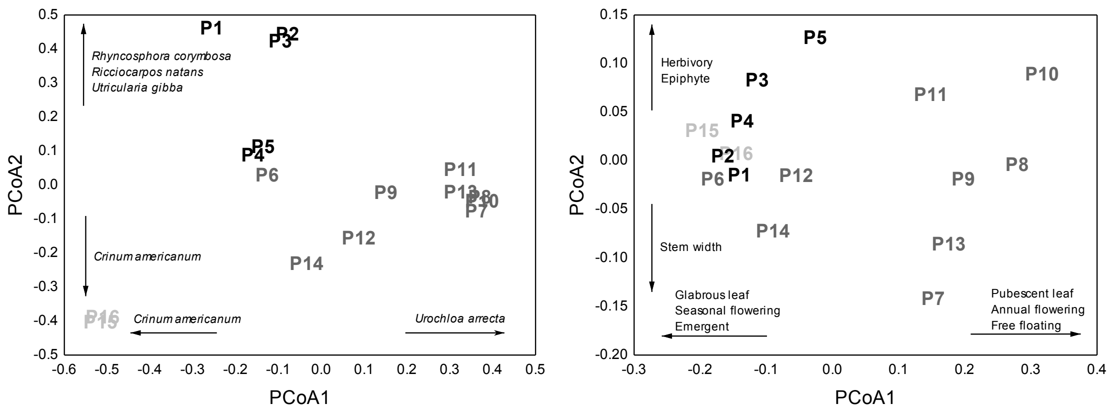


Figure 4: Principal Coordinate Analysis of the taxonomic and functional composition of aquatic macrophytes showing the centroids of macrophyte beds (across sampling periods, upper graphs) numbered from upstream to downstream (P1 to P16) and classified according to anthropogenic impact and presence of mangrove (see methods; black letters = low anthropogenic impact; dark grey letters = high anthropogenic impact; light grey letters = mangrove).

In agreement with results in Table 1, spatial variation was the main source of variation for the gamma diversity, both in percentage terms and also compared to what would be expected by a null model (Figure 5). On the other hand, mean species richness of macrophyte beds and the variation among periods were lower that it would be expected by a null model (Figure 5).

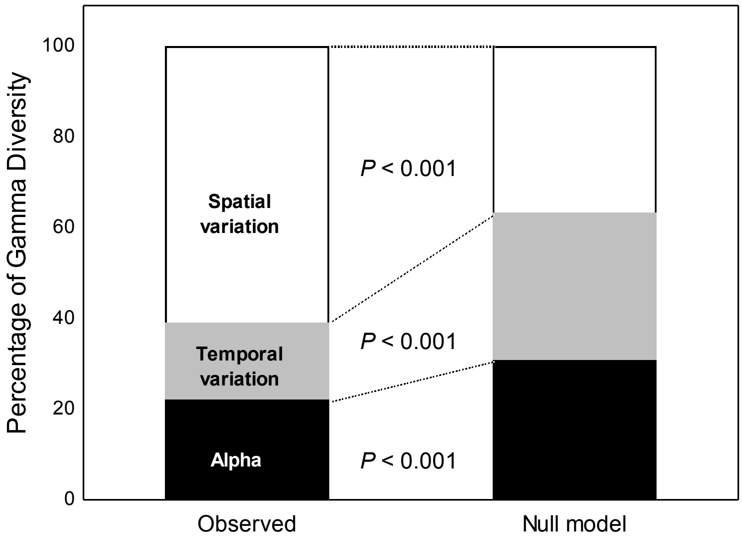


Figure 5: Additive partitioning of gamma species richness showing the observed and expected (according to a null model; see Crist et al., 2003) percentages of gamma diversity attributed to mean species richness of macrophyte beds (alpha), variation among sampling periods (temporal variation), and variation among macrophyte beds (spatial variation). *P* values lower than 0.05 indicate percentages significantly different from the null model.

The correlation between geographic distances and taxonomic dissimilarities were always significant, indicating spatial autocorrelation in the composition of aquatic macrophyte species for all periods. Considering the dissimilarity in the functional composition, there was significant correlation only in September of 2017 (the weakest among the significant ones; see Table 2).

Table 2: Spatial autocorrelation in the taxonomic and functional composition of aquatic macrophytes in the Guaragaçu River.

	Periods	**Mantel's *r***	***P***
Taxonomic dissimilarity vs. geographical distance	**Summer 2016**	**0.453**	**< 0.001**
	Winter 2016	**0.372**	**0.004**
	Summer 2017	**0.410**	**0.002**
	Winter 2017	**0.553**	**< 0.001**
	Summer 2016	-0.007	0.508
	Winter 2016	0.007	0.433

Functional dissimilarity vs. geographical distance	Summer 2017	0.142	0.095
	Winter 2017	**0.253**	**0.017**

The FRic calculated considering only interspecific trait variation represents, on average, 20.7% of the FRic estimated also considering intraspecific trait variation. Using a paired *t*-test, interspecific FRic is significantly smaller than intraspecific FRic (paired *t*: 18.695; $P < 0.001$). This indicates that most of the functional richness is determined by intraspecific variation.

There is a significant relationship between species richness and FRic, FDis and RaoQ, according to the Michaelis-Menten saturation curve. However, there is no indication that the asymptote was reached (Figure 6). Comparing the measures of functional diversity, there seems to be evidence of greater functional redundancy in FDis and RaoQ. Relationship between species richness and FDiv was not significant (Figure 6).

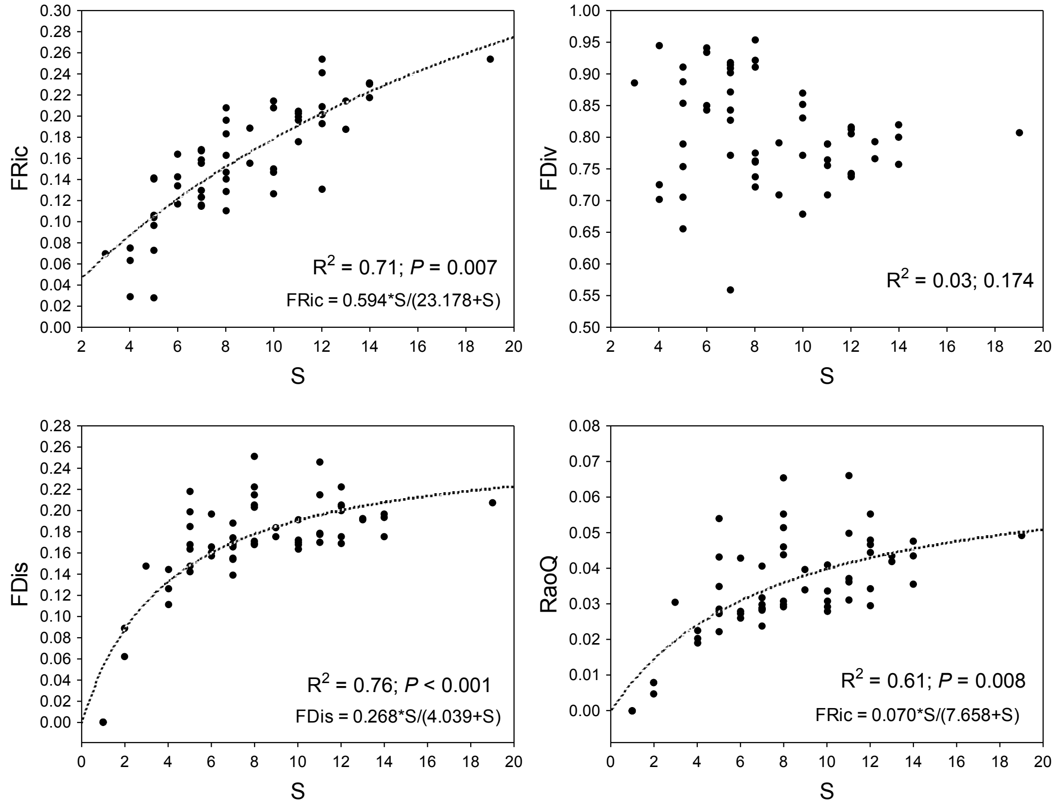


Figure 6: Michaelis-Menten Saturation curve relationship between species richness (S) and functional diversity indexes (see methods). Equations for significant fits are shown in the graph. R^2 and P are, respectively, the coefficient of explanation and type I error.

DISCUSSION

We partially supported our main hypothesis by clearly showing the spatial variation in multiple facets of diversity and community composition of macrophytes along a tidal river. We did expect such results since the study area has a conspicuous longitudinal variation considering abiotic features, and also anthropogenic impacts. According to Webb et al. (2002), high environmental heterogeneity increases the values of beta and gamma diversity, since it allows different groups of species to be distributed along different types of habitats, and allows the coexistence of many species by the absence of competition for similar resources (MacArthur 1972). Our results corroborate such hypotheses and also suggest that niche-based deterministic processes are probably the most important for the assembly of aquatic macrophyte communities in the Guaraguaçu River. Related results have been which reported for aquatic communities (Fu et al. 2014, 2017).

Regarding the temporal variation, no pattern in the taxonomic composition during the evaluated periods was verified, and only evidence for a difference between functional composition was observed from the first to the last sampling periods. Seasonal differences in rainfall, which causes increase in water level can be considered the main environmental difference among periods in LAGAMAR region (where Guaraguaçu River is located, see Camargo and Harari 2003). Also, water level variations are considered a major environmental driver of macrophytes in permanent wetlands with seasonal variation in hydrological regime (Padial et al. 2009; Rolon et al. 2010). However, our results in the Guaraguaçu river result can be explained due to the tidal influence causing a daily hydrological variation around two meters, which likely act as a selective pressure favoring those species and individuals that are already adapted to temporal variations in hydrological regime. Thus, even with the dispersal and establishment of other species, the low temporal variation of the taxonomic and functional composition indicates a possible stability of aquatic macrophyte communities in systems subject to high short-term variations. In a previous study, Bhattacharjee et al. (2007) have suggested that maintenance of species diversity or richness in humid systems is caused by intermediate disturbances, such as frequent floods, which are similar to the influence of tides. In this way, it can be affirmed that the main source of community variation of aquatic macrophytes in the temporal dynamic Guaraguaçu River is basically the spatial variation. Even so, we do recommend continuous monitoring, also based on the fact that functional composition seems to have changed considering the first and the last periods. Indeed, two years cannot be enough to evaluate temporal rends in community assembly mechanisms (see also Franklin 1989).

A clear distinction in both taxonomic and functional composition was verified in mangrove areas, an already expected result given the strong environmental filtering of such habitats (Crain et al. 2004). The eutrophication of the mangrove areas is considered as a selective factor, since they alter the chemical properties and act on the metabolism and establishment of the species (Biudes and Camargo 2006; Levine et al. 1998). Some studies also point out that interspecific competition mechanisms and physiological tolerance to abiotic stress can determine the distribution of aquatic macrophytes in mangroves (Cancian 2012; Guo and Pennings 2012; Leung 2005). Halophyte species can competitively exclude the ones that occur commonly along the river and do not exhibit salinity-tolerant physiological adaptations (Crain et al. 2004; Engels and Jensen 2010). Indeed, only few species were recorded in Guaraguaçu mangroves, and most of abundance was composed by *Crinum americanum*, a water lily that has functional traits that allow its establishment even in environments with high salinity (Nunes and Camargo 2016) is likely competitive superior than other macrophytes in Guaraguaçu mangroves.

It is evident that anthropogenic impacts have, for decades, significantly altered the geographic distributions of species, changing their richness and the rules of community assembly at different spatial scales (Elton 1958; Sax and Gaines 2003; Vitousek et al. 1997). Even so, it was not possible to verify a distinction in the taxonomic and functional diversity indexes between environments of different degrees of impact (high/low). On the other hand, the community compositions were clearly different. Such result was likely driven by the high abundance of macrophyte species that do develop in impacted areas (e.g. the damping ground nearby one of the river channels likely contribute to high nutrient inputs), mainly the non-native invasive *U. arrecta*. This species develop large beds in anthropogenic areas (see also Figure 2) and is associated to mostly floating species causing taxonomic and functional differences (Figure 4). The dense beds of *U. arrecta* may provide shelter for floating species that would be carried out by the bidirectional flow of tidal rivers. As a consequence, biodiversity values are as high as those where anthropogenic impacts are low. Even so, the conspicuous change in community composition is in line with several studies urging for impacts that *U. arrecta* is causing in Neotropical systems (Amorim et al. 2015; Michelan et al. 2010; Thomaz et al. 2009b, 2012).

The spatial autocorrelation observed here in the composition of aquatic macrophytes species is also in line with abovementioned results. The macrophyte beds presented grouping tendency with differentiated spatial patterns, with the occurrence of *Rhyncosphora corymbosa*, *Ricciocarpos natans*, and *Utricularia gibba* further upstream of the river, *U. arrecta* at the intermediate points, and *C. americanum* in the mangrove areas. Such longitudinal pattern is collinear with the classification we made: the areas further upstream of the river have a good conservation status, with typical riparian vegetation and high transparency of the water. Indeed, *Utricularia gibba* has already been described as sensitive to water pollution (Augustynowicz et al. 2015), as well as other species of the genus *Utricularia* (Gorham and Gordon 1963; Roy 1992) and bryophyte such as *Ricciocarpus natans* (Kolon 2001). The occurrence of *U. arrecta* in highly impacted areas, and *C. americanum* in mangroves were already explained before.

Interestingly, however, is that the functional composition did not present a clear pattern of spatial autocorrelation, and this is explained by the grouping tendency of functional traits. It is clear that the mean traits observed in mangroves coincide with the upstream low-impacted areas, and indeed, the high-impacted areas are the ones that mostly differ (Figure 4). Such results reinforce that spatial patterns in aquatic macrophytes are not only driven by spatial autocorrelation and continuous longitudinal change, but as a consequence of environmental filtering due to anthropogenic impacts and salinity (Guo and Pennings 2012; Nunes and Camargo 2016). Although our goal was not to discuss each predominant trait in each region, it is also interesting to note higher herbivory in upstream areas and mangroves, what could indicate that such less-impacted areas also have higher abundance and diversity of herbivores, such as insects and other aquatic invertebrates (Lodge 1991).

We also generated evidence that intraspecific variability in macrophyte traits is the most important contribution to the functional richness in the Guaraguaçu River. Particularly considering macrophytes, this fact can be attributed to the high phenotypic plasticity of the species (Caffrey et al. 2006). Other studies have found similar patterns (Cianciaruso et al. 2012; Kitchenin et al. 2013; Spasojevic et al. 2016), demonstrating that the information on intraspecific characteristics in functional ecology studies is very important to contribute to the elucidation of the rules of community assembly and biodiversity patterns.

Finally, we highlight the relevancy of some results considering the conservation of aquatic macrophyte species and ecosystem functioning. We found poor evidence of functional redundancy, but a positive relationship between species richness and most functional diversity indexes. It is already agreed that the functional richness index has a positive relation with the species richness (Bihn et al. 2010; Hejda and de Bello 2013; Petchey et al. 2009; Schleuter et al. 2014). If an asymptote is reached, then one can infer that some species are functionally redundant, and the loss of some species may not cause effects on ecosystem functioning (Naeem 1998). Therefore, we can infer that the loss of macrophyte species likely affect functional role of macrophytes in Guaraguaçu aquatic ecosystems (see related conclusions in Loreau et al.

2002; Schmera et al. 2012). Given the evident threats for macrophytes, such as strong evidences in literature for the negative effects of *U. arrecta* invasion in native macrophyte species (Michelan et al. 2010), and the key role of macrophytes in aquatic ecosystem functioning (Thomaz and Cunha 2010), our results pose a serious conservation challenge in Guaraguaçu river.

In summary, our study clearly showed the spatial structure in the aquatic macrophyte communities of the coastal and tidal Guaraguaçu River. By exploring data in different ways, we advocate that such pattern is likely caused by environmental filtering mainly due to anthropogenic impacts and salinity concentration. Also, we suggest that in dynamic systems such as tidal rivers with strong daily water level fluctuation, the seasonal variation responsible for many patterns in aquatic macrophytes in Neotropical wetlands is rather unimportant to explain community variation, although we do believe that continuous monitoring (mainly considering functional traits) is central in important areas for conservation such as the Guaraguaçu River. We also highlighted that the known high phenotypic plasticity of macrophytes contribute to macrophyte functional diversity, and that the lack of functional redundancy in macrophytes is a major conservation challenge in a key aquatic ecosystem of the Atlantic Forest hotspot.

REFERENCES

Amorim SR, Umetsu CA, Camargo AFM (2015) Effects of a non-native species of Poaceae on aquatic macrophyte community composition: a comparison with a native species. Journal of Aquatic Plant Management 53:191-196

Anderson MJ (2001) A new method for non-parametric multivariate analysis of variance. Austral Ecology 26:32–46

APG III (2009) Angiosperm Phylogeny Group. An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG III. Botanical Journal of the Linnean Society 161:105-121

Augustynowicz J, Lukowicz K, Tokarz K, Plachno BJ (2015) Potential for chromium (VI) bioremediation by the aquatic carnivorous plant Utricularia gibba L. (Lentibulariaceae). Environ Sci Pollut Res Int. 22(13):9742-9748

de Bello F, Lavorel S, Albert CH, Thuiller W, Grigulis K, Dolezal J, Janecek S, Leps J (2011) Quantifying the relevance of intraspecific trait variability for functional diversity. Methods in Ecology and Evolution 2:163–174

Bhattacharjee J, Haukos D, Neaville J (2007) Vegetation response to disturbance in a coastal marsh in Texas. Community Ecology 8(1):15-24

Bihn JH, Gebauer G, Brandl R (2010) Loss of functional diversity of ant assemblages in secondary tropical forests. Ecology 91:782-792

Biudes JFV, Camargo AFM (2006) Changes in biomass, chemical composition and nutritive value of Spartina alterniflora due to organic pollution in the Itanhaém River Basin (SP, Brazil). Brazilian Journal of Biology 66(3):781-789

Boëchat IG, Paiva ABM, Hille S, Gücker B (2013) Land-use effects on river habitat quality and sediment granulometry along a 4th-order tropical river. Revista Ambient. Água 8(3):54-64

Bornette G, Puijalon S (2011) Response of aquatic plants to abiotic factors: a review. Aquatic Sciences 73(1):1-14

Cadotte MW (2011) The new diversity: management gains through insights into the functional diversity of communities. Journal of Applied Ecology 48:1067–1069

Cadotte MW, Carscadden K, Mirotchnick N (2011) Beyond species: functional diversity and the maintenance of ecological processes and services. Journal of Applied Ecology 48:1079–1087

Caffrey JM, Dutartre A, Haury J, Murphy KM, Wade PM (2006) Macrophytes in Aquatic Ecosystems: From Biology to Management. Springer, Dordrecht, Netherlands

Camargo R, Harari J (2003) Modeling the Paranagua Estuarine Complex, Brazil: tidal circulation and cotidal charts. Rev. Bras. Oceanogr. 51:23-31

Cancian LF (2012) Modelagem de distribuição geográfica potencial de macrófitas aquáticas em bacias hidrográficas. Tese de doutorado, Universidade Estadual Paulista

Capers RS, Selsky R, Bugbee GJ (2010) The relative importance of local conditions and regional process in structuring aquatic plant communities. Freshwater Biology 55:952-966

Cardinale BJ, Duffy JE, Gonzalez A, Hooper DU, Perrings C, Venail P, Narwai A, Mace GM, Tilman D, Wardle DA, Zingiz AP, Daily GC, Loreau M, Grace JB, Larigauderie A, Srivastava DS, Naeem S (2012) Biodiversity loss and the impact on humanity. Nature 486:59-67

Carlucci M, Debastiani V, Pillar V, Duarte L (2015) Between and within-species trait variability and the assembly of sapling communities in forest patches. Journal of Vegetation Science 26:21–31

Cavalli G, Baattrup-Pedersen A, Riis T (2014) The role of species functional traits for distributional patterns in lowland stream vegetation. Freshwater Science 33:1074–1085

Ceschin F, Bini LM, Padial AA (2017) Correlates of fish and aquatic macrophyte beta diversity in the Upper Paraná River floodplain. Hydrobiologia 805(1):377-389

Cianciaruso MV, Batalha MA, Gaston KJ, Petchey OL (2009) Including intraspecific variability in functional diversity. Ecology 90(1):81-89

Cianciaruso MV, Silva IA, Batalha MA, Gaston KJ, Petchey OL (2012) The influence of fire on phylogenetic and functional structure of woody savannas: moving from species to individuals. Perspectives in Plant Ecology, Evolution and Systematics 14:205-216

Crain CM, Silliman BR, Bertness SL, Bertness MD (2004) Physical and biotic drivers of plant distribution across estuarine salinity gradients. Ecology 85(9):2539-2549

Crist TO, Veech JA, Gering JC, Summerville KS (2003) Partitioning species diversity across landscapes and regions: a hierarchical analysis of α, β, and γ-diversity. The American naturalist 162:734-743

Elton CS (1958) The ecology of invasions by animals and plants. Methuen, London

Engels JG, Jensen K (2010) Role of biotic interactions and physical factors in determining the distribution of marsh species along an estuarine salinity gradient. Oikos 119:679-685

Flynn DFB, Mirotchnick N, Jain M, Palmer MI, Naeem S (2011) Functional and phylogenetic diversity as predictors of biodiversity-ecosystem function relationships. Ecology 92:1573-1581

Fornara DA, Tilman D (2008) Plant functional composition influences rates of soil carbon and nitrogen accumulation. Journal of Ecology 96:314-322

Franklin JF (1989) Importance and Justification of Long-Term Studies in Ecology. In: Likens GE (eds) Long-Term Studies in Ecology. Springer, New York, NY

Fritz C, Schneider T, Geist J (2017) Seasonal Variation in Spectral Response of Submerged Aquatic Macrophytes: A Case Study at Lake Starnberg (Germany). Water 9(521):1-21

Fu H, Zhong J, Yuan G, Xie P, Guo L, Zhang Z, Xu J, Li Z, Li W, Zhang M, Cao T, Ni L (2014) Trait-based community assembly of aquatic macrophytes along a water depth gradient in a freshwater lake. Freshwater Biology 59:2462–2471

Fu H, Zhong J, Fang S, Hu J, Guo C, Lou Q, Yuan G, Dai T, Li Z, Zhang M, Li W, Xu J, Cao T (2017) Scale-dependent changes in the functional diversity of macrophytes in subtropical freshwater lakes in south China. Scientific Reports. 7 (8294):1-12

Gorham E, Gordon AG (1963) Some effects of smelter pollution upon aquatic vegetation eear Sudbury, Ontario. Canadian Journal of Botany 41(3):371-378

Guo H, Pennings SC (2012) Mechanisms mediating plant distributions across estuarine landscapes in a low-latitude tidal estuary. Ecology 93(1):90-100

Hejda M, de Bello F (2013) Impact of plant invasions on functional diversity in the vegetation of Central Europe. Journal of Vegetation Science 24:890-897

Kichenin E, Wardle DA, Peltzer DA, Morse CW, Freschet GT, Kitajima K (2013) Contrasting effects of plant inter and intraspecific variation on community-level trait measures along an environmental gradient. Functional Ecology 27:1254-1261

Kolon K (2001) The sensitivity of water liverworts *Riccia fluitans* L. and *Ricciocarpus natans* [L.] Corda to selected polycyclic aromatic hydrocarbons 79:145-150

Laliberté E, P Legendre (2010) A distance-based framework for measuring functional diversity from multiple traits. Ecology 91:299-305

Lana PC, Marone EL, Lopes RM, Machado EC (2001) The subtropical estuarine complex of Paranaguá Bay, Brazil. In: Seeliger U, Lacerda LD, Kjerfve BJ (eds) Coastal marine ecosystems of Latin America. Springer, Berlin, pp 131-145

Lavorel S, Grigulis K, McIntyre S, Williams NSG, Garden D, Dorrough J, Berman S, Quétier F, Thébault A, Bonis A (2008) Assessing functional diversity in the field - methodology matters! Functional Ecology 22:134-147

Leung R (2005) Distribuição de macrófitas aquáticas em relação a variáveis ambientais em ecossistemas lóticos da Bacia do rio Itanhaém. Tese de doutorado, Universidade Estadual Paulista

Levine JM, Brewer JS, Bertness MD (1998) Nutrients, competition and plant zonation in a New England salt marsh. Journal of Ecology 86:285-292

Li K, Wang L, Li Z, Xie Y, Wang X, Fang Q (2017) Spatial and temporal variation of aquatic plant abundance: Quantifying change. Water 9(707):1-17

Lodge DM (1991) Herbivory on freshwater macrophytes. Aquatic Botany 41(1-3):195-224

Loreau M, Downing AL, Emmerson MC, Gonzalez A, Hughes J, Inchausti P, Joshi J, Norberg J, Sala O (2002) A new look at the relationship between diversity and stability. In: Loreau M, Naeem S, Inchausti P (eds) Biodiversity and Ecosystem Functioning. Synthesis and Perspectives. Oxford University Press, Oxford, pp 79-91

MacArthur RH (1972) Geographical ecology. Harper & Row, New York

Maltchik L, Rolon AS, Schott P (2007) Effects of hydrological variation on the aquatic plant community in a fl oodplain palustrine wetland of southern Brazil. Limnology 8:23-28

Magnusson WE, Lima AP, Luizão R, Luizão F, Costa FRC, Castilho CV, Kinupp VF (2005) RAPELD: A modification of the gentry method for biodiversity surveys in long-term ecological research sites. Biota Neotropica 5(2):1-6

Magurran AE (2013) Measuring Biological Diversity. Willey, Nova Jersey, EUA

Michelan TS, Thomaz SM, Mormul RP, Carvalho P (2010) Effects of an exotic invasive macrophyte (tropical signalgrass) on native plant community composition, species richness and functional diversity. Freshwater Biology 55:1315–1326

Michelan TS, Thomaz SM, Bini LM (2013) Native Macrophyte Density and Richness Affect the Invasiveness of a Tropical Poaceae Species. Plos One 8(3):1-8

Mouchet MA, Villeger S, Mason NWH, Mouillot D (2010) Functional diversity measures: an overview of their redundancy and their ability to discriminate community assembly rules. Functional Ecology 24(4):867-876

Moura-Júnior EG, Lima LF, Silva SSL, Paiva RMS, Ferreira FA, Zickel CS, Pott A (2015) Aquatic macrophytes of Northeastern Brazil: Checklist, richness, distribution and life forms. Check List 9(2):298-312

Myers N, Mittermeier RA, Mittermeier CG, Fonseca GAB, Kent J (2000) Biodiversity hotspots for conservation priorities. Nature 403:853-858

Naeem S (1998) Species redundancy and ecosystem reliability. Conservation Biology 12:39-45

Naeem S, Li S (1997) Biodiversity enhances ecosystem reliability. Nature, 390:507-509

Nunes LSC, Camargo AFM (2016) Do interspecific competition and salinity explain plant zonation in a tropical estuary? Hydrobiologia https://doi.org/10.1007/s10750-016-2821-8

Padial AA, Carvalho P, Thomaz SM, Boschilia SM, Rodrigues RB, Kobayashi JT (2009) The role of an extreme flood disturbance on macrophyte assemblages in a Neotropical floodplain. Aquatic Sciences 71(4): 389-398

Pavão AC, Santos ACA, Bottino F, Benassi RF, Calijuri MC (2017) Richness and distribution of aquatic macrophytes in a subtropical reservoir in São Paulo, Brazil. Acta Limnologica Brasiliensia 29(10): 1-11

Pedralli G (1990) Macrófitos aquáticos: técnicas e métodos de estudos. Estudos de Biologia 26: 5-24

Pérez-Harguindeguy N, Díaz S, Garnier E et al (2013) New handbook for standardised measurement of plant functional traits worldwide. Australian Journal of Botany 61:167-234

Petchey OL, Gaston KJ (2006) Functional diversity: back to basics and looking forward. Ecology Letters 9:741-758

Petchey OL, Gorman EJO, Flynn DFB (2009) A functional guide to functional diversity measures. In: Naeem S, Bunker DE, Hector A, Loreau M, Perrings C. (eds.) Biodiversity, ecosystem functioning and human wellbeing: An ecological and economic perspective. Oxford, Oxford University Press. p. 49-59

Pott VJ, Pott A (2000) Plantas aquáticas do Pantanal. Brasília: EMBRAPA. 353p

Queiroz FLL, Rocha PC (2010) Avaliação de sedimentos do leito no canal Curutuba / planície fluvial do alto rio Paraná, Mato Grosso do Sul - Brasil. Revista AGB/TL 7(11):147-164

R Core Team (2017) R: A language and environment for statistical computing. http:// www.R–project.org/

Riis T, Lambertini C, Olesen B, Clayton JS, Brix H, Sorrel BK (2010) Invasion strategies in clonal aquatic plants: are phenotypic differences caused by phenotypic plasticity or local adaptation? Annals of Botany 106(5):813-822

Rodrigues ASL, Malafaia G, Castro PTA (2010) A importância da avaliação do habitat no monitoramento da qualidade dos recursos hídricos: uma revisão. SaBios 5(1):26-42

Rolon AS, Homem HF, Maltchik (2010) Aquatic macrophytes in natural and managed wetlands of Rio Grande do Sul State, Southern Brazil. Acta Limnol. Bras. 22(2):133-146

Roy S, Ihantola R, Hanninen O (1992) Peroxidase activity in lake macrophytes and its relation to pollution tolerance. Environmental and Experimental Botany 32(4):457-464

Sax DF, Gaines SD (2003) Species diversity: from global decreases to local increases. Trend in Ecology and Evolution 18(11):561-566

Schleuter AD, Daufresne M, Massol F, Argillier C, Monographs SE, August N (2014) A user‘s guide to functional diversity indices A user‘s. Ecological Monographs 80:469-484

Schmera D, Baur B, Erõs T (2012) Does functional redundancy of communities provideinsurance against human disturbances? An analysis usingregional-scale stream invertebrate data. Hydrobiologia 693(1):183-194

Schultz R, Dibble E (2012) Effects of invasive macrophytes on freshwater fish and macroinvertebrate communities: the role of invasive plant traits. Hydrobiologia 684(1): 1-14

Silva FFG (2008) Composição e distribuição da ictiofauna do Rio Guaraguaçu (Paranaguá, Paraná-BR) e biologia alimentar de três espécies. Dissertaçõ de Mestrado, Universidade Federal do Paraná

Socolar JB, Gilroy JJ, Kunin WE, Edwards DP (2016) How Should Beta-Diversity Inform Biodiversity Conservation? Trends in Ecology & Evolution 31(1):67-80

Spasojevic MJ, Turner BL, Myers, JA (2016) When does intraspecific trait variation contribute to functional beta-diversity? Journal of Ecology 104:487-496

StatSoft Inc. (2005) STATISTICA (data analysis software system), version 7.1. www.statsoft.com.

Thomaz SM, Carvalho P, Padial AA, Kobayashi JT (2009a) Temporal and spatial patterns of aquatic macrophyte diversity in the Upper Paraná River floodplain. Brazilian Journal of Biology 69:617-625

Thomaz SM, Carvalho P, Mormul RP, Ferreira FA, Silveira MJ, Michelan TS (2009b) Temporal trends and effects of diversity on occurrence of exotic macrophytes in a large reservoir. Acta Oecologica 35:614-620

Thomaz SM, Cunha ER (2010) The role of macrophytes in habitat structuring in aquatic ecosystems: methods of measurement, causes and consequences on animal assemblages' composition and biodiversity. Acta Limnol. Bras. 22(2):218-236

Thomaz SM, Silveira MJ, Michelan TS (2012) The colonization success of an exotic Poaceae is related to native macrophyte richness, wind disturbance and riparian vegetation. Aquatic Sciences 74(4): 809-815

Tilman D (2001) Functional diversity. In: Levin SA (ed.) Encyclopedia of Biodiversity. San Diego, Academic Press. pp 109-120

Villéger S, Mason NWH, Mouillot D (2008) New multidimensional functional diversity indices for a multifaceted framework in functional ecology. Ecology 89:2290–2301

Violle C, Navas ML, Vile D, Kazakou E, Fortunel C, Hummel I, Garnier E (2007) Let the concept of trait be functional! Oikos, 116:882–892

Vitousek PM, Mooney HA, Lubchenco J, Melillo JM (1997) Human Domination of Earth's Ecosystems. Science, New Series, 277(5325):494-499

Vitule JRS (2007) Distribuição, abundância e estrutura populacional de peixes introduzidos no Rio Guaraguaçu, Paranaguá, Paraná, Brasil. Tese de Doutorado, Universidade Federal do Paraná

Vitule JRS, Umbria SC, Aranha JMR (2006) Introduction of the African catfish *Clarias gariepinus* (Burchell, 1822) into Southern Brazil. Biol Invations 8:677-681

Ward JV, Stanford JA (1983) The serial discontinuity concept in lotic ecosystems. *In*: Fontaine, T. D.; Barthell, S. M. (Eds.). Dynamics of lotic ecosystems. Michigan: Ann Arbor Science

Webb CO, Ackerly DD, Mcpeek MA, Donoghue MJ (2002) Phylogenies and community ecology. Annual Review of Ecology and Systematics, Palo Alto 33(1):475-505

SUPPLEMENTARY MATERIAL

Metadata of macrophyte community composition and functional traits in 16 macrophyte beds in Guaraguaçu River, Paraná, Brazil in 2016 and 2017

Title: Macrophyte community composition and functional traits in 16 macrophyte beds in Guaraguaçu River, Paraná, Brazil in 2016 and 2017

Owners:

Individuals: André Andrian Padial and Elielton da Silva Araújo
Organization: Universidade Federal do Paraná - UFPR
Address: Departamento de Botânica - SCB, Centro Politécnico,
Av. Francisco Heráclito dos Santos, s/n, Jardim das Américas, CEP 81531-990,
Curitiba, Paraná, Brasil
Phone: +55 41 3360 11790 (voice)
Email Address: aapadial@gmail.com
Web Address: lattes.cnpq.br/6957024195477387

Abstract: The data from community composition and 11 functional traits of aquatic macrophytes in Guaraguaçu River were sampled in March/April and September/October of 2016 and 2017 to understand distribution pattern related to ecological gradients.

Key-words:
Aquatic Plants
Aquatic Macrophytes
Atlantic Forest
Invasive species
Coastal Basin
Hydrophytes plants
Paraná
Brazil
Guaraguaçu River
Lagamar

License and Usage Rights: All data are available for using, but pending on contact owners. Collaboration in future scientific papers are encouraged.

Geographical extension: Data were sampled over the navigable strecth of Guaraguaçu River, in a watercourse extension of nearly 34.5, between latitudes -48.55505699 and -48.49023404; and between longitudes -25.68864402 and -25.72649997. The total Guaraguaçu área is inserted in Environmental Protection Area of Guaratuba, and parto f its course is surrouded by the State Reserves "Estação Ecológica do Rio Guaraguaçu" and "Floresta do Palmito". The sampled area is representative of aquatic vegetation of coastal rivers from LAGAMAR region in Matinhos, Pontal do Paraná and Paranaguá municipalities, Paraná State, Brazil.

Coordinates of macrophyte beds:

Macrophyte beds	Latitude	Longitude
1	-25.7644	-48.5551
2	-25.7599	-48.5517
3	-25.756	-48.5495
4	-25.7421	-48.5467
5	-25.7265	-48.5555
6	-25.6985	-48.5283
7	-25.6965	-48.5234
8	-25.6995	-48.5157
9	-25.6886	-48.4963
10	-25.6877	-48.5181
11	-25.6626	-48.5161
12	-25.6523	-48.5012
13	-25.6401	-48.4987
14	-25.624	-48.4792
15	-25.6124	-48.4903
16	-25.5995	-48.4902

Sampling months:

March and April of 2016, September and October of 2016, March and April of 2017, September and October of 2017.

Contact:

Individual: André Andrian Padial – aapadial@gmail.com / +55 41 33611790

Definition of data in table. Full sampling methods are available in Elielton da Silva Araújo Masters Dissertation available at http://www.portal.ufpr.br/teses_acervo.html

Taxa in the table were identified to the lowest taxonomic level. Most taxa were identified to species level, although information is available only for genera for taxa with dubious classification during trait measurements. Absent trait measurements are possible for some taxa in some macrophyte bed. The following information is available at the table:

SAMPLING_SITE: identifying that samplings were made in Guaraguaçu

SAMPLING_POINT: identification of macrophyte bed sampled (see coordinates above).

DATE: last month in which sampling were made.

SPECIES: taxa sampled (some are only in genus level).

INDIVIDUAL: module number sampled for trait measurements. Up to three modules for each taxa in each macrophyte bed were sampled for trait measurements.

A50: abundance of the taxa considering the 50 m extension of the macrophyte bed (same value for all modules).

AL: local abundance of the module (Braun-Blanquet coverage classes in a 0.5 x 0.5 cm quadrat).

ROL: root length (cm).

LEL: leaf length (cm).

LEW: leaf width (cm).

LEA: leaf area (LEL x LEW, cm^2).

PEL: petiole length (cm).

STW: stem width (cm).

HER: herbivory, measured as Braun-Blanquet classes considering the percentage of leaf area covered by herbivory.

LFO: life form (emergent, rooted floating, free floating, rooted submerged, free submerged, amphibian, epiphyte).

FLO: flowering duration (seasonal or annual).

LEP: leaf pubescence (pubescent or glabrous).

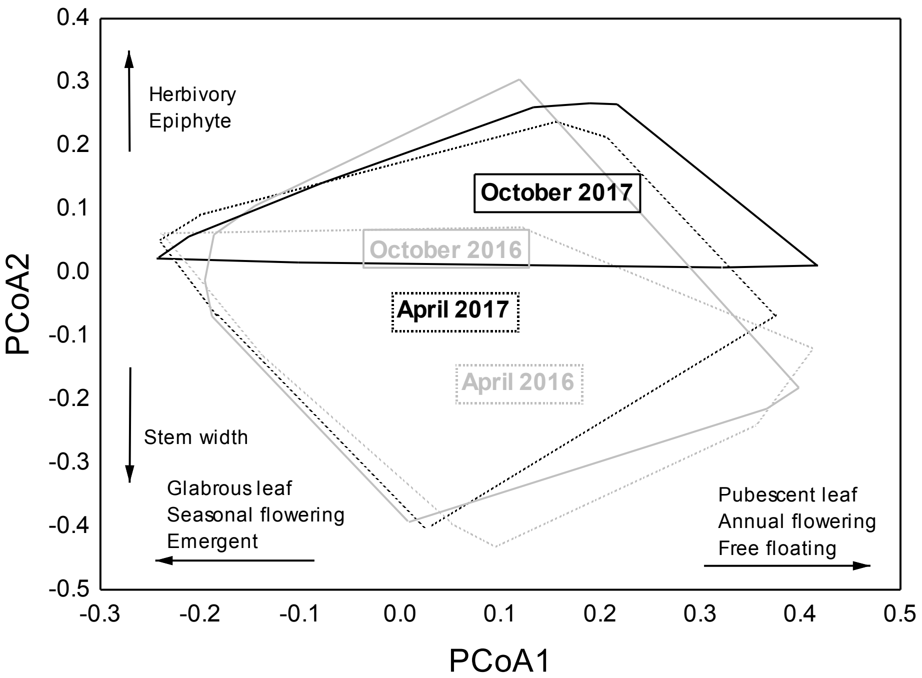


Figure S1. Principal Coordinate Analysis of the functional composition of aquatic macrophytes showing scores for each period. Main traits considering correlation with PCoA axes are shown. Periods are differentiated in the graph considering dashed and continuous line, and the color of the fonts.

CAPÍTULO III

Mácrofitas Aquáticas do Rio Guaraguaçu, Paraná, Brasil

Curitiba, 2017

UNIVERSIDADE FEDERAL DO PARANÁ
CURSO DE PÓS-GRADUAÇÃO EM ECOLOGIA E CONSERVAÇÃO

Prancha botânica produzida por Lima (2011)

Mácrofitas Aquáticas do Rio Guaraguaçu, Paraná, Brasil

Elielton Araújo & André Padial

Curitiba, 2017

Apresentação

As macrófitas aquáticas correspondem a um grupo ecológico que vai desde as macroalgas até as angiospermas, que vivem parcial ou inteiramente dentro d'água. Esse grupo ecológico apresenta reconhecida importância ecológica e socioeconômica e por isso são consideradas importante componente estrutural para o funcionamento dos ecossistemas aquáticos continentais.

O Rio Guaraguaçu é formado por confluências de outros rios que nascem na Serra da Prata e desagua na Baía de Paranaguá, litoral do Paraná, Brasil.

As macrófitas aquáticas do rio vêm sendo investigadas de forma mais intensiva desde 2014, início dos projetos PELD – LAGAMAR e rede PPBio – Mata Atlântica (subprojeto LAGAMAR). Com as investigações realizadas, as espécies ocorrentes foram oficialmente registradas e depositadas no Herbário do Departamento de Botânica da Universidade Federal do Paraná (UPCB).

Esse guia se refere as espécies de macrófitas aquáticas coletadas no Rio Guaraguaçu e faz parte da dissertação de Mestrado Ecologia e Conservação do primeiro autor, bem como do Monitoramento PELD-LAGAMAR, financiado pelo CNPq. Acreditamos que as informações aqui depositadas servirão de base para identificação das espécies em campo, bem como subsidiar outros trabalhos realizado no rio Guaraguaçu. É importante ressaltar que esse guia será constantemente atualizado após novas coletas. Confira sempre!

Os autores

Lista de espécies

- *Alternanthera philoxeroides* (Mart.) Griseb. (tripa-de-sapo)
- *Apalanthe granatensis* (Bonpl.) Planch. (lodinho-branco)
- *Azolla caroliniana* Willd. (azola)
- *Begonia fischeri* Schrank (azedinha-do-brejo)
- *Ceratopteris thalictroides* (L.)Brongn. (samambaia-d'água, couve-d'água)
- *Commelina nudiflora* L. (trapoeraba, erva-de-Santa-Luzia)
- *Crinum americanum* L. (lírio-rajado)
- *Cyperus giganteus* Vahl (piri, piripiri, pirizeiro)
- *Echinodorus grandiflorus* (Cham. & Schltr.) Micheli (chapéu-de-couro, erva-do-brejo)
- *Echinodorus tenellus tenellus* (Mart. ex. Roem. & Schult.) Buchenau (erva-do-pântano)
- *Egeria densa* Planch. (elódea)
- *Eichhornia azurea* (Sw.) Kunth (camalote, mureré)
- *Eichhornia crassipes* (Mart.) Solms (baronesa, aguapé)
- *Eleocharis geniculata* (L.) Roem. & Schult. (cebolinha)
- *Eleocharis interstincta* (Vahl) Roem. & Schult. (cebolinha)
- *Eleocharis tenuissima* Boeckeler (cebolinha)
- *Habenaria repens* Nutt. (orquídea)
- *Hydrocotyle leucocephala* Cham. & Schltdl. (erva-capitão, orelha-de-onça-rasteira)
- *Hymenachne amplexicaulis* (Rudge) Nees (capim-de-capivara)
- *Ipomoea carnea* Jacq. (algodão-bravo)
- *Ludwigia erecta* (L.) H.Hara
- *Ludwigia grandiflora* (Michx.) Greuter & Burdet (florzeiro)
- *Ludwigia helminthorrhiza* (Mart.) H.Hara (lombrigueira)
- *Ludwigia octovalvis* (Jacq.) P.H.Raven (cruz-de-malta)
- *Myriophyllum aquaticum* (Vell.) verdc. (pinheirinho-d'água)
- *Nymphaea caerulea* Savugny (ninfeia-azul"
- *Oxycaryum cubense* (Poepp. & Kunth) Lye (baceiro, capim-de-capivara)
- *Palhinhaea cernua* (L.) Franco & Vasc. (pinheirinho, musgão)
- *Panicum aquaticum* Poir. (canarana, capim-de-tartaruga)
- *Panicum schwackeanum* Mez (capim-do-banhado)
- *Begonia fischeri* Schrank (azedinha-do-brejo)
- *Pistia stratiotes* L. (alface-d'água)
- *Polygonum hydropiperoides* Michx. (erva-de-bicho)
- *Polygonum punctatum* Elliott (ver-de-bicho)
- *Polygonum stelligerum* Cham. (erva-de-bicho)
- *Potamogeton illinoensis* Morong
- *Rhynchospora corymbosa* (L.) Britton (capim-navalha)
- *Ricciocarpos natans* (L.) Corda
- *Salvinia biloba* Raddi (orelha-de-onça)
- *Talipariti pernambucense* (Arruda) Bovini (hibisco-do-mangue)
- *Tibouchina trichopoda* (DC.) Baill.
- *Typha dominguensis* Pers. (taboa)
- *Urochloa arrecta* (Hack. ex T.Durand & Schinz) Morrone & Zuloaga (braquiária)
- *Utricularia gibba* L. (utriculária)
- *Wedelia paludosa* DC. (vedélia, mal-me-quer)

Alternanthera philoxeroides (Mart.) Griseb.

"tripa-de-sapo"

Fotos: A) Hábito; B) Detalhe da inflorescência

Família: Amaranthaceae
Distribuição no Brasil: AM, AP, PA, AL, BA, PB, PE, RN, SE, MS, MT, ES, MG, SP, PR, RS, SC.
Forma biológica: Anfíbia
Características botânicas: Erva perene ou anual, raramente subarbusto. Apresenta estolões, caule oco, folhas com ápice agudo, base decurrente e pecíolo de 0,2 a 1cm. Flores diminutas alvas.
Observações e características ecológicas: Em alguns ambientes pode ser indicador de perturbação, bem como, utilizada como controle biológico.
Ref: Barroso et al., 2002; Flora do Brasil, 2017; Pott & Pott, 2000.

Apalanthe granatensis (Bonpl.) Planch.

"lodinho-branco"

Fotos: A) Hábito; B) Detalhe da flor.

Família: Hydrocharitaceae
Distribuição no Brasil: AM, PA, RO, TO, BA, CE, MA, PB, PE, PI, RN, SE, GO, MS, MT, MG, RJ, SP, PR.
Forma biológica: Submersa fixa
Características botânicas: Erva perene de até 15 cm. Folhas verticiladas e macias abaixo da lâmina d'água. Flores hermafroditas brancas com três estames.
Observações e características ecológicas: A coleta no rio Guaraguaçu resultou no primeiro registro para o Estado do Paraná.
Ref: Flora do Brasil, 2017; Lourenço & Bove, 2017.

Azolla caroliniana Willd.

"azola"

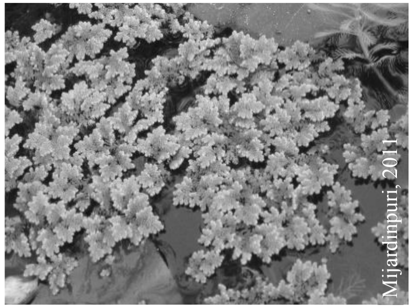
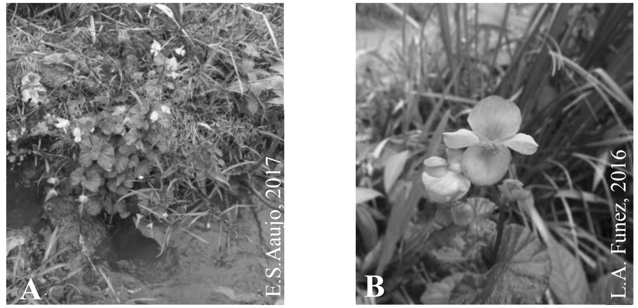


Foto: Hábito

Família: Salviniaceae
Distribuição no Brasil: AC, AM, PA, BA, CE, PB, PE, MS, MT, ES, MG, RJ, SP, PR, RS, SC.
Forma biológica: Flutuante livre
Características botânicas: Erva perene de cerca de 7 a 25mm de diâmetro, ramificada, com folhas verde-amareladas imbrificadas. Raízes escuras. Apresenta alta capacidade de propagação.
Observações e características ecológicas: Apresenta simbiose com cianobactérias para fixação de nitrogênio. Por isso há frequentemente alterações na pigmentação entre o verde e o marrom.
Ref: Flora do Brasil, 2017; Toledo & Penha, 2011.

Begonia fischeri Schrank

"azedinha-do-brejo"



Fotos: A) Hábito; B) Detalhe da flor.

Família: Begoniaceae
Distribuição no Brasil: RO, BA, PE, DF, GO, MS, MT, ES, MG, RJ, SP, PR, RS, SC.
Forma biológica: Anfíbia
Características botânicas: Erva pilosa ca. de 0,3-1m alt. Caules eretos avermelhados, folhas ovadas e simples com ápice agudo. Flores rosadas com estames amarelados.
Observações e características ecológicas: Espécie encontrada nas margens de locais com baixa velocidade de correnteza.
Ref: Kollmann, 2006; Flora do Brasil, 2017.

Ceratopteris thalictroides (L.)Brongn.
"samambaia-d'água, couve-d'água"

Fotos: A) Hábito; B) Detalhe da flor.

Família: Pteridaceae
Distribuição no Brasil: AM, AP, PA, RO, AL, BA, CE, MA, PB, PE, RN, SE, ES, RJ, SP, PR, RS, SC.
Forma biológica: Anfíbia
Características botânicas: Pteridófita anual de 20-50 cm. Apresenta rizoma ereto e curto. As folhas estéreis são largas e as férteis são partidas e enroladas nas margens para proteção dos esporângios. Estas estruturas geralmente se encontram espalhadas pelas nervuras, tendo em média 32 esporos.
Observações e características ecológicas: Espécie típica de água corrente e aumenta próximo a áreas perturbadas.
Ref: Flora do Brasil, 2017; Amoroso, 2007.

Commelina nudiflora L.
"trapoeraba, erva-de-Santa-Luzia"

Fotos: A) Hábito; B) Detalhe da flor.

Família: Commelinaceae
Distribuição no Brasil: AM, AP, PA, AL, BA, CE, PB, PE, RN, SE, RJ, SP, PR, RS, SC.
Forma biológica: Anfíbia
Características botânicas: Erva perene. Folhas lanceoladas e flores azuis ou quase brancas.
Observações e características ecológicas: Apresenta alto potencial forrageiro e alta propagação em locais perturbados.
Ref: Flora do Brasil, 2017; Ujowundu, 2008.

Crinum americanum L.
"lírio-rajado"

Fotos: A) Hábito; B) Detalhe da flor.

Família: Amaryllidaceae
Distribuição no Brasil: AC, AM, AP, PA, RO, TO, AL, BA, CE, MA, PB, PB, PI, RN, SE, MS, MT, ES, MG, RJ, SP, PR, RS, SC.
Forma biológica: Emergente
Características botânicas: Espécie perene com bulbos de 3,5 a 6cm de diâmetro. Folhas glabras e flores alvas. Espécie não-nativa com alto valor ornamental.
Observações e características ecológicas: Espécie invasora com alta frequência em nas margens de ambientes ricos em nutrientes. Apresenta tolerância a salinidade.
Ref: Flora do Brasil, 2017; Missouri Botanical Garden, 2017.

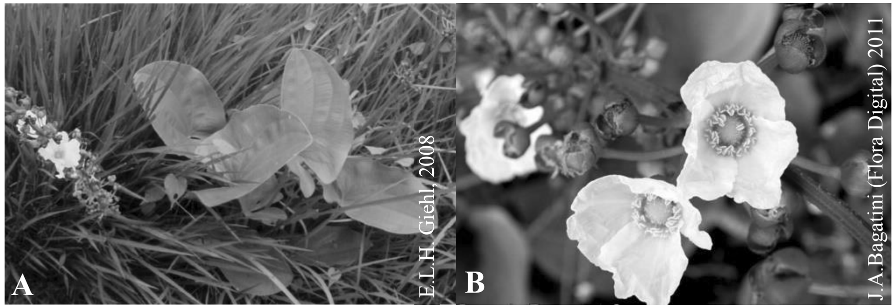
Cyperus giganteus Vahl
"piri, piripiri, pirizeiro"

Fotos: A) Hábito; B) Detalhe da flor.

Família: Cyperaceae
Distribuição no Brasil: AC, AM, AP, PA, RO, RR, TO, AL, BA, CE, MA, PB, PE, PI, SE, DF, GO, MS, MT, ES, MG, RJ, SP, PR, RS, SC.
Forma biológica: Emergente
Características botânicas: Espécie herbácea, perene de até 3m de alt. Rizomas com entrenós curtos e espessados, folhas com bainhas. Inflorescência tipo espigueta verdes quando imaturas e marrons quando maduras.
Observações e características ecológicas: Ocorre em grande extensão do rio. Os espécimes que ocorrem no rio têm características morfológicas diferentes do que os descritos na literatura, podendo ser uma sub-espécie ou mesmo outra espécie. Porém, não há ainda a posição de especialistas a respeito.
Ref: Flora do Brasil, 2017; Hefler & Longhi-Wagner, 2012.

Echinodorus grandiflorus (Cham. & Schltr.) Micheli

"chapéu-de-couro, erva-do-brejo"



Fotos: A) Hábito; B) Detalhe da flor.

Família: Alismataceae
Distribuição no Brasil: AC, AL, BA, CE, MA, PB, PE, PI, SE, DF, GO, MS, MT, ES, MG, RJ, SP, PR, RS, SC.
Forma biológica: Emergente
Características botânicas: Espécie herbácea perene. Caule triangular e glabro com rizoma rateiro. Folhas simples e basais. Flores alvas, trímeras, dispostas em panículas verticiladas. Infrutescências esféricas, verdes quando imaturas e castanhas quando maduras.
Observações e características ecológicas: Apresenta muitos bancos durante a estação chuvosa, mas desaparece na seca.
Ref: Flora do Brasil, 2017. Pott & Pott, 2000.

Echinodorus tenellus tenellus (Mart. ex. Roem. & Schult.) Buchenau

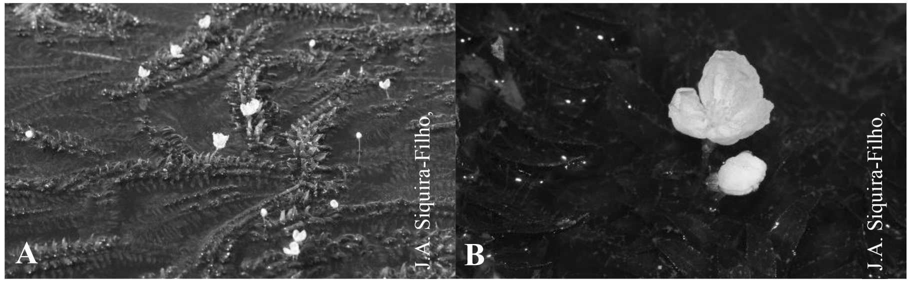
"erva-do-pântano"

Foto: Hábito e detalhe da flor.

Família: Alismataceae
Distribuição no Brasil: AM, BA, PE, PI, MS, MT, MG, RJ, SP, PR, RS, SC.
Forma biológica: Anfíbia
Características botânicas: Erva perene e estolonífera e formando pequenas touceiras. Caule longo de até 6m. Folhas maiores que entrenós. Flores diminutas alvas.
Observações e características ecológicas: Apresenta propagação apenas vegetativa.
Ref: Flora do Brasil, 2017; Hefler & Longhi-Wagner, 2012.

Egeria densa Planch.

"elódea"

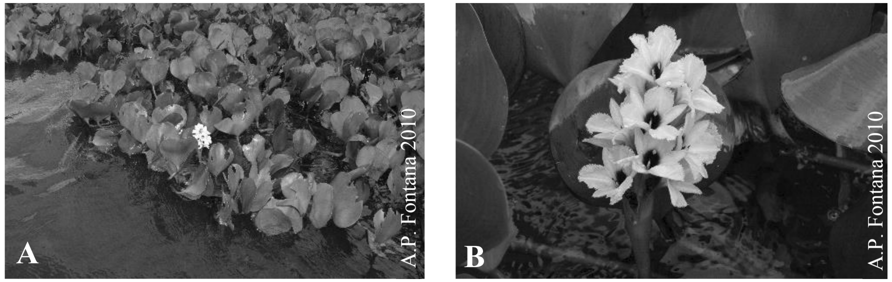


Fotos: A) Hábito; B) Detalhe da flor.

Família: Hydrocharitaceae
Distribuição no Brasil: AL, BA, CE, PB, PE, SE, ES, MG, RJ, SP, PR, RS, SC.
Forma biológica: Submersa fixa
Características botânicas: Erva frequente com estruturas vegetativas abaixo da lâmina d´água. Folhas simples e verticiladas. Flores trímeras, alvas com estigmas amarelos.
Observações e características ecológicas: Importante indicadora de eutrofização e perturbação. Apresenta riscos econômicos em represas de hidroelétricas.
Ref: Flora do Brasil, 2017;

Eichhornia azurea (Sw.) Kunth

"camalote, mureré"



Fotos: A) Hábito; B) Detalhe da inflorescência.

Família: Pontederiaceae
Distribuição no Brasil: AM, AP, PA, RO, RR, TO, AL, BA, PE, SE, ES, MG, RJ, SP, PR, RS, SC.
Forma biológica: Flutuante livre
Características botânicas: Erva perene e rizomatosa de 1-8 m de comprimento. Folhas sempre verdes com aerênquimas nos tecidos que permitem a flutuação. Inflorescência com flores lilases claro externamente e lilases escuro internamente. Guia de nectário amarelo.
Observações e características ecológicas: Foi avistada somente uma vez, sendo que o congênere *E. crassipes* é a espécie mais comum e abundante em toda a extensão do rio.
Ref: Flora do Brasil, 2017; Pott & Pott, 2000.

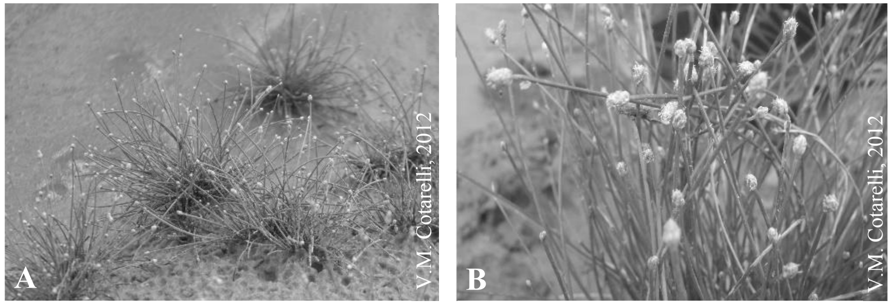
Eichhornia crassipes (Mart.) Solms

“baronesa, aguapé”

Fotos: A) Hábito; B) Detalhe da inflorescência.
Família: Pontederiaceae
Distribuição no Brasil: AC, AM, PA, RO, RR, TO, AL, BA, CE, MA, PB, PE, PI, RN, DF, GO, MS, MT, ES, MG, RJ, SP, PR, RS, SC.
Forma biológica: Flutuante livre
Características botânicas: Erva perene de 15-80 cm de altura. Folhas alternas espiraladas. Flores lilases apresentando estandarte com uma pinta amarela. Diferencia-se de *E. azurea* pela coloração das flores, sendo esta um lilás mais claro e homogêneo, além das pétalas apresentarem bordo liso.
Observações e características ecológicas: Apresenta alto risco econômico em represas de hidroelétricas.
Ref: Flora do Brasil, 2017; Pott & Pott, 2000.

Eleocharis geniculata (L.) Roem. & Schult.

“cebolinha”



Fotos: A) Hábito; B) Detalhe da inflorescência.
Família: Cyperaceae
Distribuição no Brasil: PA, RO, TO, AL, BA, CE, MA, PB, PE, PI, RN, SE, DF, GO, MS, MT, ES, MG, RJ, SP, PR, RS, SC.
Forma biológica: Anfíbia
Características botânicas: Erva cespitosa. Caule não septado. Folhas paralelinérvias. Inflorescência tipo espigueta verde quando imatura e marrom quando madura. Flores inconspícuas.
Observações e características ecológicas: As espécies desse gênero ocorrem de forma misturada em uma seção a montante do rio, podem haver mais espécies.
Ref: Flora do Brasil, 2017; Gil & Bove, 2007.

Eleocharis interstincta (Vahl) Roem. & Schult.

“cebolinha”

Fotos: A) Hábito; B) Detalhe da inflorescência.
Família: Cyperaceae
Distribuição no Brasil: Registro em todos os estados.
Forma biológica: Emergente
Características botânicas: Erva frequente cespitosa com caule cilíndrico e oco. Inflorescências terminais alvas.
Observações e características ecológicas: As espécies desse gênero ocorrem de forma misturada em uma seção a montante do rio, podem haver mais espécies.
Ref: Flora do Brasil, 2017; Pott & Pott, 2000.

Eleocharis tenuissima Boeckeler

“cebolinha”

Foto: Hábito e detalhe da flor.
Família: Cyperaceae
Distribuição no Brasil: AM, AP, PA, RO, TO, BA, CE, MA, PB, PE, PI, RN, DF, GO, MS, MT, ES, MG, RJ, SP, PR, RS, SC.
Forma biológica: Emergente
Características botânicas: Erva filamentosa. Inflorescência diminuta tipo espigueta verde quando imatura e marrom quando madura. Flores inconspícuas. Diferencia-se das outras por ser uma erva minúscula com vários filamentos com inflorescência terminal
Observações e características ecológicas: As espécies desse gênero ocorrem de forma misturada em uma seção a montante do rio, podem haver mais espécies.
Ref: Flora do Brasil, 2017; Gil & Bove, 2007.

Habenaria repens Nutt.
"orquídea"

Fotos: A) Hábito; B) Detalhe da inflorescência.

Família: Orchidaceae
Distribuição no Brasil: PA, BA, CE, PE, DF, GO, MS, MT, ES, MG, RJ, SP, PR, RS, SC.
Forma biológica: Emergente
Características botânicas: Folhas variegadas. Flores alvas com esporão, pétalas bipartidas.
Observações e características ecológicas: Foi avistada somente uma vez, e com apenas dois indivíduos na região a montante do rio.
Ref: Flora do Brasil, 2017; Rocha & Waechter, 2006.

Hydrocotyle leucocephala Cham. & Schltdl.
"erva-capitão, orelha-de-onça-rasteira"

Fotos: A) Hábito; B) Detalhe da inflorescência.
Família: Araliaceae
Distribuição no Brasil: BA, CE, PB, MS, MT, ES, MG, RJ, SP, PR, RS, SC.
Forma biológica: Flutuante fixa
Características botânicas: Erva perene com caule subterrâneo; Folhas simples membranácia. Flores diminutas esbranquiçadas, dispostas em umbelas eretas.
Observações e características ecológicas: Planta daninha que ocorre em terrenos alagadiços, margens de rios e lagoas.
Ref: Flora do Brasil, 2017; Lorenzi, 2008.

Hymenachne amplexicaulis (Rudge) Nees

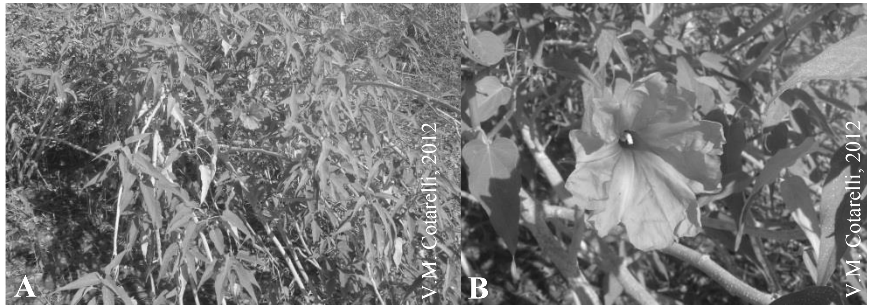
"capim-de-capivara"

Fotos: A) Hábito; B) Detalhe da inflorescência.

Família: Poaceae
Distribuição no Brasil: Todos os estados com exceção de SE.
Forma biológica: Emergente
Características botânicas: Erva ereta fixa. Inflorescências tipo espiguetas verdes quando imaturas e marrons quando maduras, bainhas arroxeadas. Flores inconspícuas alvas.
Observações e características ecológicas: Sem inflorescência, se confunde com a invasora *U. arrecta*, pois co-ocorre em vários locais do rio. Apresenta tendência de ter folhas mais largas e caules grossos.
Ref: Flora do Brasil, 2017; Sturza, 2011.

Ipomoea carnea Jacq.

"algodão-bravo"



Fotos: A) Hábito; B) Detalhe da flor.

Família: Convolvulaceae
Distribuição no Brasil: Todos os estados com exceção de Rondônia.
Forma biológica: Anfíbia
Características botânicas: Trepadeiras herbáceas de 1-4 m de ltur. Presença de látex. Folhas membranáceas. Flores tubulosas lilases.
Observações e características ecológicas: Os ramos acompanham o regime hidrológico, depois da cheia caem ao solo e enraízam.
Ref: Flora do Brasil, 2017; Lorenzi, 2008.

Ludwigia erecta (L.) H.Hara

Fotos: A) Hábito; B) Detalhe da flor.

Família: Onagraceae
Distribuição no Brasil: AM, AP, RO, AL, BA, CE, MA, PB, PE, DF, MG, RJ, SP, PR.
Forma biológica: Anfíbia
Características botânicas: Erva frequente de 20-70 cm de ltura. Folhas em espiral, pecíolos vináceos. Flores amarelas com ovário ínfero. Cálice persistente.
Observações e características ecológicas: Coloniza solo desnudo por perturbação ou pela cheia, e banco de areia e lama em rio.
Ref: Flora do Brasil, 2017; Kadiri & Olowokudejo, 2010.

Ludwigia grandiflora (Michx.) Greuter & Burdet
"florzeiro"

Fotos: A) Hábito; B) Detalhe da flor.

Família: Onagraceae
Ocorrência no Brasil: MS, MT, SP, PR, SC.
Forma biológica: Emergente
Características botânicas: Erva a arbusto com pilosidade no caule, folhas e flores. Folhas do ramo floral lanceoladas. Flores pentâmeras amarelas, com estrutura estigmática alvas.
Observações e características ecológicas: Prostrada no início da colonização, com ramos eretos quando se estabelece.
Ref: Flora do Brasil, 2017; Bertuzzi et al., 2011.

Ludwigia helminthorrhiza (Mart.) H.Hara
"lombrigueira"

Fotos: A) Hábito; B) Detalhe da flor.

Família: Onagraceae
Distribuição no Brasil: PA, BA, CE, MS, RJ, SP, PR, SC.
Forma biológica: Flutuante livre
Características botânicas: Erva perene 50 cm de comprimento. Raízes esponjosas (pneumatóforos) flutuantes. Flores brancas e estames amarelados.
Observações e características ecológicas: Sobrevive em lama úmida, mas desaparece em períodos de seca, após investir em muitas flores e sementes.
Ref: Flora do Brasil, 2017; Ramamoorthy & Zardini, 1987.

Ludwigia octovalvis (Jacq.) P.H.Raven
"cruz-de-malta"

Fotos: A) Hábito; B) Detalhe da flor.

Família: Onagraceae
Distribuição no Brasil: AC, AM, PA, RO, TO, AL, BA, CE, M, PB, PE, PI, RN, SE, DF, GO, MS, MT, ES, MG, RJ, SP, PR, SC.
Forma biológica: Emergente
Características botânicas: Erva anual ou perene de 5-50 cm. Folhas simples e opostas. Flores tetrâmeras amarelas com cálice persistente.
Observações e características ecológicas: Coloniza solo desnudo por perturbação, sendo indicadora destes ambientes.
Ref: Flora do Brasil, 2017; Munz, 1947.

Myriophyllum aquaticum (Vell.) verdc.
"pinheirinho-d'água"

Fotos: A) Hábito; B) Detalhe da flor.

Família: Haloragaceae
Distribuição no Brasil: AL, BA, SE, MS, MT, ES, MG, RJ, SP, PR, RS, SC.
Forma biológica: Submersa fixa
Características botânicas: Erva. Caule longo de até 6m. Folhas maiores que entrenós. Flores diminutas alvas.
Observações e características ecológicas: Apresenta grandes bancos em águas claras e com baixa velocidade da correnteza.
Ref: Flora do Brasil, 2017; Hefler & Longhi-Wagner, 2012.

Nymphaea caerulea Savugny
"ninfeia-azul"

Fotos: A) Hábito; B) Detalhe da flor.

Família: Nymphaeaceae
Distribuição no Brasil: BA, ES, MG, RJ, SP, PR, RS, SC.
Forma biológica: Submersa fixa
Características botânicas: Folhas com pecíolo avermelhado, glabrescente. Flores lilases com estames e anteras amarelados.
Observações e características ecológicas: Invasora não-nativa (originária da África).
Ref: Flora do Brasil, 2017; Lima, 2011.

Oxycaryum cubense (Poepp. & Kunth) Lye

“baceiro, capim-de-capivara”

Fotos: A) Hábito; B) Detalhe da flor.

Família: Cyperaceae
Distribuição no Brasil: Registros em todos os estados
Forma biológica: Epífita
Características botânicas: Erva ereta, cespitosa. Inflorescência tipo espigueta verdes quando imaturas e marrons quando maduras.
Observações e características ecológicas: Colonizadora de ilhas flutuantes, especialmente *E. crassipes* e *Salvinia auriculata*. Inici-se como epífita e depois torna-se dominante.
Ref: Flora do Brasil, 2017.

Palhinhaea cernua (L.) Franco & Vasc.

“pinheirinho, musgão”

Fotos: Hábito

Família: Lycopodiaceae
Ocorrência no Brasil: AC, AM, AP, PA, RO, RR, TO, AL, BA, CE, MA, PB, PE, DF, GO, MS, MT, ES, MG, RJ, SP, PR, RS, SC.
Forma biológica: Anfíbia
Características botânicas: Pteridófita perene de até 1 m com ramos estoloníferos arqueados. Ramos principais eretos, laterais alternos e sub-opostos e terminais pendentes. Estróbilos apicais numerosos. Esporângios globosos.
Observações e características ecológicas: Considerada ruderal ocorrendo principalmente em locais ensolarados com acúmulo sazonal de água ou em barrancos úmidos.
Ref: Flora do Brasil, 2017; Salino & Arruda, 2016.

Panicum aquaticum Poir.
"canarana, capim-de-tartaruga"

Fotos: A) Hábito; B) Detalhe da inflorescência.

Família: Poaceae
Distribuição no Brasil: AC, AM, PA, BA, CE, MA, PB, PE, RN, DF, GO, MS, MT, ES, MG, RJ, SP, PR, RS, SC.
Forma biológica: Emergente
Características botânicas: Erva perene rizomatosa de 1-2 m. Folhas lanceoladas, glabras. Inflorescência tipo espiguetas com glumas (membranas escariosas) desenvolvidas. Flores inconspícuas.
Observações e características ecológicas: Aumenta com perturbação do solo e locais de pisoteio.
Ref: Flora do Brasil, 2017; Pott & Pott, 2000.

Panicum schwackeanum Mez
"capim-do-banhado"

Fotos: Exsicata.

Família: Poaceae
Distribuição no Brasil: AM, AP, PA, RO, BA, DF, GO, MS, MT, ES, MG, RJ, SP, PR, RS, SC.
Forma biológica: Emergente
Características botânicas: Erva perene de cerca de 10-70 cm. Folhas lanceoladas glabras. Inflorescência panículas. Flores inconspícuas.
Observações e características ecológicas: Sensível a locais perturbadas principalmente com perturbação.
Ref: Flora do Brasil, 2017; Vorontsova, Clayton & Simon, 2015.

Pistia stratiotes L.

“alface-d’água”

Fotos: A) Hábito; B) Detalhe da inflorescência.
Família: Araceae
Distribuição no Brasil: AC, AM, AP, PA, AL, BA, CE, MA, PB, PE, PI, RN, SE, ES, MG, RJ, SP, PR, RS, SC.
Forma biológica: Flutuante livre
Características botânicas: Erva perene rosulada. Caule estolonífero; Raízes pilosas e adventícias. Folhas esponjosas em roseta. Espádice amarelada.
Observações e características ecológicas: Ocorre com grande desenvolvimento nas regiões com maior impacto antrópico, provavelmente pela grande quantidade de nutrientes na água. Nesses locais, atinge grandes tamanhos (cerca de 50 cm de diâmetro).
Ref: Flora do Brasil, 2017; Neuenschwander et al., 2009.

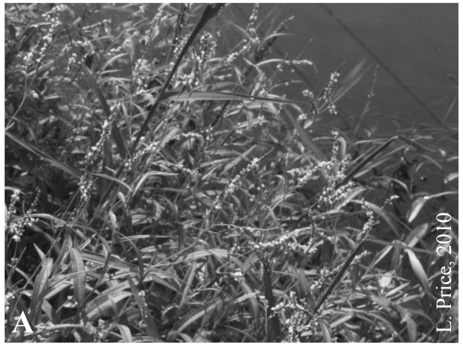
Polygonum hydropiperoides Michx.

“erva-de-bicho”

Fotos: Detalhe da inflorescência.
Família: Polygonaceae
Distribuição no Brasil: AP, PA, RO, RR, TO, BA, CE, MA, PB, PE, PI, SE, DF, GO, MS, MT, ES, MG, RJ, SP, PR, RS, SC.
Forma biológica: Emergente
Características botânicas: Erva frequente. Folhas lanceoladas com tricomas nas margens. Inflorescência racemosa com flores diminutas brancas, branco-esverdeadas ou vináceas.
Observações e características ecológicas: Considerada invasora de cultivo em solos úmidos e arrozal.
Ref: Flora do Brasil, 2017; Melo, 1996.

Polygonum punctatum Elliott

"ver-de-bicho"



Fotos: A) Hábito; B) Detalhe da inflorescência.

Família: Polygonaceae
Distribuição no Brasil: AC, AM, PA, RR, AL, BA, CE, MA, PB, PE, PI, SE, DF, GO, MS, MT, ES, MG, RJ, SP, PR, RS, SC.
Forma biológica: Anfíbia
Características botânicas: Erva perene. Folhas glabras e lanceoladas. Inflorescência racemosa com flores diminutas brancas ou rosadas com perianto amarronzado.
Observações e características ecológicas: Muito frequente em locais com perturbação do solo e considerada invasora de culturas.
Ref: Flora do Brasil, 2017; Melo, 1996.

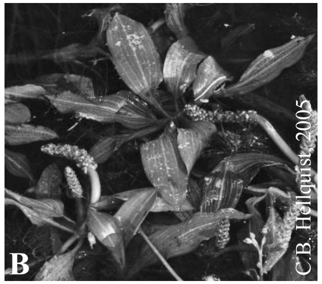
Polygonum stelligerum Cham.

"erva-de-bicho"

Fotos: A) Hábito; B) Detalhe da inflorescência.

Família: Polygonaceae
Distribuição no Brasil: MS, MT, SP, PR, RS, SC.
Forma biológica: Anfíbia
Características botânicas: Erva perene. Folhas longo-pecioladas de base sagitada com tricomas retrosos. Inflorescência terminal e axilar com flores diminutas brancas, branco-esverdeadas ou vináceas.
Observações e características ecológicas: Muito abundante em leito vazante, brejos e solos ricos em matéria orgânica.
Ref: Flora do Brasil, 2017; Melo, 1996.

Potamogeton illinoensis Morong



Fotos: A) Hábito; B) Detalhe da inflorescência.

Família: Potamogetonaceae
Distribuição no Brasil: AM, BA, CE, PE, PI, MS, MT, RJ, SP, PR, RS, SC.
Forma biológica: Flutuante livre
Características botânicas: Erva frequente em corredeiras de 30-120 cm. Folhas membranáceas, pecioladas. Inflorescências de 10-15 cm formando espigas aéreas. Apresentam pedúnculos não dimórficos, terminais ou axilares. Flores diminutas.
Observações e características ecológicas: Ocorrência bem restrita no rio, nas regiões com características tipicamente fluviais (fluxo unidirecional e grande de água).
Ref: Flora do Brasil, 2017; Haynes & Hellquist, 1993.

Rhynchospora corymbosa (L.) Britton

"capim-navalha"

Foto: Hábito.

Família: Cyperaceae
Distribuição no Brasil: Registro em todos os estados.
Forma biológica: Emergente
Características botânicas: Espécie perene. Inflorescência em paniculódio, com o eixo central dominante. Cerdas peroginais presentes.
Observações e características ecológicas: Considerada ocasional. Muito frequente em brejos e solos ricos em matéria orgânica.
Ref: Flora do Brasil, 2017; Silveira & Longhi, Wagner, 2008.

Ricciocarpos natans (L.) Corda

Foto: Hábito.

Família: Ricciaceae
Distribuição no Brasil: AM, PA, BA, PE, MS, MT, ES, RJ, SP, PR, RS, SC.
Forma biológica: Flutuante livre
Características botânicas: Hepática perene de 1-1,5 cm de comprimento. Talos flutuantes verde-amarelados em formas de rosetas. No sulco longitudinal desenvolvem-se os órgãos sexuais (arquegônios negros e anterídios).
Observações e características ecológicas: Cresce em locais ricos em nutrientes. Pioneira na ocupação da superfície ou espalhada no meio da vegetação aquática.
Ref: Flora do Brasil, 2017; Sergio et al., 2006.

Salvinia biloba Raddi
"orelha-de-onça"

Foto: Hábito.

Família: Salviniaceae
Distribuição no Brasil: PA, BA, PE, RN, ES, MG, RJ, SP, PR, RS, SC.
Forma biológica: Flutuante livre
Características botânicas: Erva com rizomas flutuantes horizontais, sem raízes verdadeiras. Folhas dobradas e tricomadas na face adaxial. Apresenta um eixo fértil compacto com esporocarpos aglomerados.
Observações e características ecológicas: Tem grande plasticidade no tamanho e forma, podendo ser confundida com seus congêneres *S. auriculata* e *S. minima*. É importante sempre investigar as características para ver se não há registros desses congêneres.
Ref: Flora do Brasil, 2017; Rodrigues, 2011.

Talipariti pernambucense (Arruda) Bovini

“hibisco-do-mangue”

Fotos: A) Hábito; B) Detalhe da flor.

Família: Malvaceae
Distribuição no Brasil: PA, AL, BA, CE, PB, PE, RN, SE, ES, RJ, SP, PR, RS, SC.
Forma biológica: Anfíbia
Características botânicas: Arbusto frequente no mangue. Folhas alternas e coriáceas com um par de estípulas caducas. Flores penduculadas, solitárias ou dispostas em inflorescências cimosas. Apresenta uma colocação amarela com uma transição pra vermelho quando entram em estádio de senescência.
Observações e características ecológicas: “Ribeirinha”, colonizadora de ilhas e margens dois rios. Considerada pioneira na vegetação ripária.
Ref: Flora do Brasil, 2017; Bovini, 2010.

Tibouchina trichopoda (DC.) Baill.

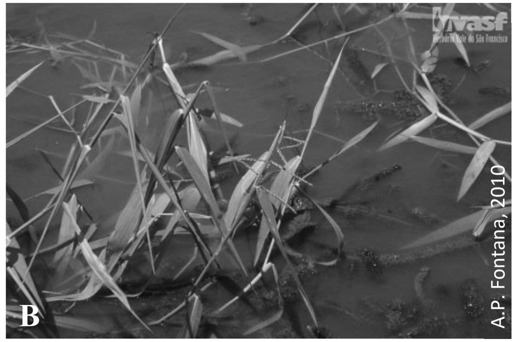
Fotos: A) Hábito; B) Detalhe da flor.

Família: Melastomataceae
Distribuição no Brasil: ES, MG, RJ, SP, PR, RS, SC.
Forma biológica: Anfíbia
Características botânicas: Arbusto a arvoreta pioneira e perenifólia. Folhas simples e opostas, tricomadas. Flores pentâmeras roxas. Apresenta tricomas no cálice.
Observações e características ecológicas: Muito frequente em solos siltosos ou arenosos ácidos com superfície orgânica.
Ref: Flora do Brasil, 2017; Meyer, 2008.

Typha dominguensis Pers.
"taboa"

Fotos: A) Hábito; B) Detalhe da inflorescência.
Família: Typhaceae
Distribuição no Brasil: Todos es estados brasileiros.
Forma biológica: Emergente
Características botânicas: Espécie herbácea paludosa, perene, de rizoma rasteiro. Flores dispostas em racimos castanho-avermelhados. Espiga masculina mais fina e disposta acima da feminina.
Observações e características ecológicas: Há bastante abundância em regiões brejosas vizinhas ao rio, mas efetivamente tem pouca ocorrência em suas margens.
Ref: Flora do Brasil, 2017; Silva, 2014.

Urochloa arrecta (Hack. ex T.Durand & Schinz) Morrone & Zuloaga
"braquiária"

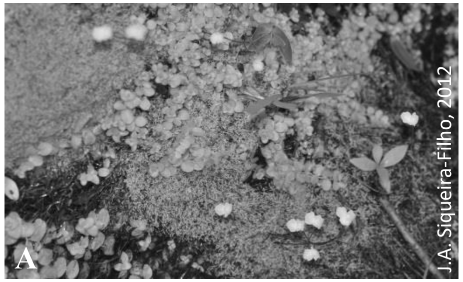


Fotos: A) Hábito; B) Detalhe da inflorescência.

Família: Poacee
Distribuição no Brasil: AM, BA, CE, MA, PB, PE, GO, MS, MG, SP, PR, RS, SC.
Forma biológica: Emergente
Características botânicas: Erva perene, estolonífera com enraizamento nos nós inferiores em contato com o solo. Folhas lanceoladas. Inflorescência em racemos e do tipo espiguetas glabras e bisseriadas.
Observações e características ecológicas: Espécie não nativa (originária da África) e invasora. De longe a com maior abundância no rio, mostrando sua alta capacidade de invasão.
Ref: Flora do Brasil, 2017; Gouveia-Santos, 2001.

Utricularia gibba L.

"utriculária"



Fotos: A) Hábito; B) Detalhe da inflorescência.

Família: Lentibulariceae
Distribuição no Brasil: AM, PA, AL, BA, CE, MA, PB, PE, PI, RN, SE, GO, MS, MT, ES, MG, RJ, SP, PR, RS, SC.
Forma biológica: Submersa livre
Características botânicas: Erva perene com caule estolonífero e flores amarelas sendo o lábio superior da corola oval a orbicular. Apresenta muitos utrículos globosos nas partes vegetativas dos indivíduos.
Observações e características ecológicas: Cresce em áreas protegidas por vegetação. Indicadora de ambientes oligotróficos.
Ref: Flora do Brasil, 2017; Correia & Mamede, 2002

Wedelia paludosa DC.

"vedélia, mal-me-quer"

Foto: Flor.

Família: Asteraceae
Distribuição no Brasil:
Forma biológica: Anfíbia
Características botânicas: Erva perene de 30-70 cm. Ramos glabros às vezes avermelhados. Folhas opostas frequentemente trilobadas. Inflorescência capítulos solitários, terminais com flores amarelas.
Observações e características ecológicas: Colonizadora de material orgânico de fundo de lago e de brejos.
Ref: Flora do Brasil, 2017; Moraes & Monteiro, 2006.

Referências Bibliográficas

- Amoroso, V.B. 2007. Pteridophyte and Gymnosperm Diversity in Musuan, Bukidnon. *Philippine Journal os Systematic Biology.* Vol. 1, N. 1: 1-14.
- Barroso, G.M.; Peixoto, A.L.; Ichaso, C.L.F.; Guimarães, E.F. & Costa, C.G. 2002. *Sistemática de Angiospermas do Brasil.* Vol. 1, 2ª ed. Viçosa, MG. Editora UFV – Universidade Federal de Viçosa, 309p.
- Bertuzzi, T.; Grigoletto, D.; Canto-Dorow, T.S. & Eisinger, S.M. 2011. O gênero *Ludwigia* L. (Onagraceae) no Município de Santa Maria, Rio Grande do Sul, Brasil.
- Bovini, M.G. 2010. A new combination in the genus Talipariti (Malvaceae). *Rodriguésia* 61(Sup.): S19-S21.
- Correia, M.A. & Mamede, M.C.H. 2002. Lentibulariaceae In: Wanderley, M.G.L., Shepherd, G.J., Giulietti, A.M., Melhem, T.S., Bittrich, V., Kameyama, C. (eds.) *Flora Fanerogâmica do Estado de São Paulo.* Instituto de Botânica, São Paulo, vol. 2, pp: 141-154.
- Endress, A.G. 1974. Spore Germination of Ceratopteris thalictroides (L.) Brongn. Annals of Botany New Series, Vol. 38, No. 157. pp. 877-881
- Gil, A.S.B. & Bove, C.P. 2007. *Eleocharis* R.Br. (Cyperaceae) no Estado do Rio de Janeiro, Brasil. *Biota Neotrop.* vol.7 no.1
- Gouveia-Santos, A. 2001. Urochloa. In: M.G.L. Wanderley, G.J. Shepherd & A.M. Giulietti (orgs.). *Flora Fanerogâmica do Estado de São Paulo: Poaceae.* FAPESP & HUCITEC, São Paulo, v.1, pp. 243-245.
- Guglieri, A.; Longhi-Wagner, H.M. & Zuloaga, F.O. 2007. *Panicum* Sect. *Dichotomiflora* (Hitchc. & Chase) Honda e P. sect. *Virgata* Hitchc. & Chase ex Pilg. (Poaceae: Panicoideae: Paniceae) no Brasil. Acta Botanica Brasilica, Porto Alegre, v. 21, n. 4, p. 785-805.
- Haynes, R.R. & Hellquist,C.B. 1993. Potamogetonaceae. In: *Flora of North America: north of Mexico*, vol. 2.
- Hefler, S.M. & Longhi-Wagner, H.M. 2012. Cyperus L. subg. Cyperus (Cyperaceae) na Região Sul do Brasil. *R. bras. Bioci.*, Porto Alegre, v. 10, n. 3, p. 327-372.

- Kadiri, A.B, & Olowokudejo, J.D. 2010. Systematic significance of foliar epidermal morphology in the West African species of Ludwigia (Onagraceae). *Phytologia Balcanica* 16 (1): 57 – 64
- Kollmann, L.J.C. 2006. Begoniaceae da Estação Biológica de Santa Lúcia, municipio de Santa Teresa, Estado do Espírito Santo, Brasil. *Boletim do Museu de Biologia Mello Leitão* 20: 07-25.
- Lima, C.T. 2011. *A ordem Nymphaeales no Estado da Bahia, Brasil*. Dissertação de Mestrado (Botânica)- Universidade Estadual de Feira de Santana, Feira de Santana-BA, Brasil.
- Lorenzi, H. 2008. *Plantas Daninhas do Brasil: Terrestres, Aquáticas, Parasitas e Tóxicas.* Instituto Plantarum. Nova Odessa, SP, 4ª ed. 672p.
- Lourenço, A.R. & Bove, C.P. 2017. Flora do Rio de Janeiro: Hydrocharitaceae. *Rodriguésia* 68(1): 043-050.
- Melo, E. 1996. O gênero Pollygonum L. (Polygonaceae) no Estado da Bahia, Brasil. *Sitientibus*, 14: 45-55.
- Meyer, F.S. 2008. O gênero *Tibouchina* Aubl. (Melastomataceae) no Estado do Paraná, Brasil. Dissertação de Mestrado (Botânica)- Universidade Federal do Paraná, Curitiba-PR, Brasil.
- Missouri Botanical Garden, 2017. *Plant List*. Shaw Boulevard, St. Louis, MO, 63110 USA
- Moraes, M. D.; Monteiro, R. 2006. A Família Asteraceae na Planície Litorânea de Picinguaba, Ubatuba, São Paulo; *Hoehnea* 33(1): 41-78, 59f
- Munz, P.A. 1947. Onagráceas. In: Hoehne, F.C. (Ed.). *Flora Basilica*, v. 41, n. 1, p. 1-62.
- Neuenschwander P, Julien MH, Center TD & Hill MP (2009) *Pistia stratiotes* L. (Araceae). In: *Biological Control of Tropical Weeds Using Arthropods* (Eds Muniappan R, Reddy GVP & Raman A), pp. **332–352**. Cambridge University Press, London, UK.
- Pott, V.J. & Pott, A. 2000. *Plantas Aquáticas do Pantanal*. Embrapa. Centro de Pesquisa Agropecuária do Pantanal, Corumbá-MS. 404p.

- Ramamoorthy, T.P. & Zardini, E.M. 1987. The systematics and evolution of *Ludwigia* sect. *Myrtocarpus* sensu lato. *Monograph Systematic Botany. (Missouri Botanical Garden)*, v. 19, p. 1-120.
- Rocha, F.S. & Waechter, J.L. 2006. Sinopse das Orchidaceae terrestres ocorrentes no litoral norte do Rio Grande do Sul, Brasil. *Acta Botanica Brasilica.* 20(1): 71-86
- Rodrigues, M.E.F. 2011. *Levantamento Florístico e distribuição de macrófitas aquáticas na Represa Guarapiranga, São Paulo, Brasil.* Dissertação de mestrado (Botânica) – Universidade de São Paulo, São Paulo-SP, Brasil.
- Salino, A. & Arruda, A.J. 2016. Flora das cangas da Serra dos Carajás, Pará, Brasil: Lycopodiaceae. *Rodriguésia* 67, n. 5 (Especial): 1159-1161.
- Sérgio, C.; Brugués, M.; Cros, C. & Garcia, C. 2006. The 2006 Red List and an updated Checklist of bryophytes of the Iberian Peninsula (Portugal, Spain and Andorra). *Lindbergia* 31: 109-125.
- Silva, C.O. 2014. Características anatômicas e fisiológicas de *Thypa dominguensis* Pers. submetida a concentrações de arsênio. Dissertação de Mestrado (Botânica Aplicada) – Universidade Federal de Lavras, Lavras-MG, Brasil.
- Silveira, G.H. & Longhi-Wagner, H.M. 2008. Cyperaceae Juss. no Morro Santana – Porto Alegre e Viamão, Rio Grande do Sul, Brasil. *Iheringia*, Sér. Bot., v. 63, n. 2, p. 295-320.
- Sturza, V.S.; Machado, S.L.O.; Silva, K.S. & Santos, A.B. 2011. Forage quality of ‘capim-capivara’ on lowlands in the central region of Rio Grande do Sul, Brazil. *Ciência Rural*, Santa Maria, Online.
- Toledo, J.J. & Penha, J. 2011. Performance of Azolla caroliniana Willd. and Salvinia auriculata Aubl. on fish farming efluente. *Braz. J. Biol.* vol.71 no.1
- Ujowundu, C.O.; Igwe, C.U.; Enemor, V.H.A; Nwaogu, L.A. & Okafor, O.E. 2008. Nutritive and Anti-Nutritive Properties of *Boerhavia diffusa* and *Commelina nudiflora* Leaves. *Pakistan Journal of Nutrition* 7 (1): 90-92

- Vorontsova, M.S.; Clayton, D. & Simon, B.K. 2015. Grassroots e-floras in the *Poaceae*: growing GrassBase and GrassWorld. *PhytoKeys*. (48): 73–84.

Referências

AGOSTINHO, A.A.; THOMAZ, S.M.; GOMES, L.C. Conservação da biodiversidade em águas continentais do Brasil. **Megadiversidade** 1(1):70–78, 2005.

ALBERT, C.H.; DE BELLO F.; BOULANGEA T.I.; PELLET, G.; LAVOREL, S.; THUILLER, W. On the importance of intraspecific variability for the quantification of functional diversity. **Oikos** 121:116–126, 2012.

ALVES, J.A.A., TAVARES, A.S. & TREVISAN, R. Composição e distribuição de macrófitas aquáticas na lagoa da Restinga do Massiambu, Área de Proteção Ambiental Entorno Costeiro, SC. **Rodriguésia** 62(4): 785-801, 2011.

AMORIM, S.R.; UMETSU, C.A; CAMARGO, A.F.M. Effects of a non-native species of Poaceae on aquatic macrophyte community composition: a comparison with a native species. **Journal of Aquatic Plant Management** 53: 191-196, 2015.

AMOROSO, V.B. Pteridophyte and Gymnosperm Diversity in Musuan, Bukidnon. **Philippine Journal os Systematic Biology** 1(1):1-14, 2007.

ANDERSON, M.J. A new method for non-parametric multivariate analysis of variance. **Austral Ecology**, 26: 32–46, 2001.

APG III. Angiosperm Phylogeny Group. An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG III. **Botanical Journal of the Linnean Society** 161: 105-121, 2009.

ARAUJO, E.S.; SABINO, J.H.F.; COTARELLI, V.M.; SIQUEIRA-FILHO, J.A.; CAMPELO, M.J.A. Riqueza e diversidade de macrófitas aquáticas em mananciais da Caatinga. **Dialogos&Ciencia**, 32, 229-233, 2012.

ARROYO-RODRÍGUEZ, V.; MELO, F.P.; MARTÍNEZ-RAMOS, M.; BONGERS, F.; CHAZDON, R.L.; MEAVE, J.A.; NORDEN, N.; SANTOS, B.A.; LEAL, I.R; TABARELLI, M. Multiple successional pathways in human-modified tropical landscapes: new insights from forest succession, forest fragmentation and landscape ecology research. **Biol Rev Camb Philos Soc.**. 92(1):326-340, 2015.

ASEFA, M.; CAO, M.; ZHANG, G.; CI, X.; LI, J.; YANG, J. Environmental filtering structures tree functional traits combination and lineages across space in tropical tree assemblages. **Nature** 7 (132):1-10, 2017.

AUGUSTYNOWICZ, J.; LUKOWICZ, K.; TOKARZ, K. & PLACHNO, B.J. Potential for chromium (VI) bioremediation by the aquatic carnivorous plant Utricularia gibba L. (Lentibulariaceae). **Environ Sci Pollut Res Int**. 22(13): 9742-9748, 2015.

DE BELLO, F.; LAVOREL, S.; ALBERT, C.H.; THUILLER, W.; GRIGULIS, K.; DOLEZAL, J.; JANECEK, S.; LEPS, J. Quantifying the relevance of intraspecific trait variability for functional diversity. **Methods in Ecology and Evolution** 2: 163–174, 2011.

BARRELA, W.; MARTINS, A.B.; PETRETE-JR, M. RAMIRES, M. Fishes of the southeastern Brazil Atlantic Forest. **Environ Biol Fish**. 97 (12): 1367-1376, 2014.

BARROSO, G.M.; PEIXOTO, A.L.; ICHASO, C.L.F.; GUIMARÃES, E.F.; COSTA, C.G. **Sistemática de Angiospermas do Brasil**. Vol. 1, 2ª ed. Viçosa, MG. Editora UFV – Universidade Federal de Viçosa, 309p, 2002.

BERTUZZI, T.; GRIGOLETTO, D.; CANTO-DOROW, T.S.; EISINGER, S.M. **O gênero *Ludwigia* L. (Onagraceae) no Município de Santa Maria, Rio Grande do Sul, Brasil.** 2011.

BHATTACHARJEE, J.; HAUKOS, D.; NEAVILLE, J. Vegetation response to disturbance in a coastal marsh in Texas. **Community Ecology**, vol. 8, no. 1, p. 15-24, 2007.

BIANCHINI JR., I.; PACOBAHYBA, L.D.; CUNHA-SANTINO, M.B. Aerobic and anaerobic decomposition of *Montrichardia arborescens* (L.) Schott. **Acta Limnologica Brasiliensia** 14(3):27-34, 2002.

BIHN, J.H.; GEBAUER, G.; BRANDL, R. Loss of functional diversity of ant assemblages in secondary tropical forests. **Ecology** 91: 782-792, 2010.

BINI, L.M.; THOMAZ, S.M.; MURPHY, K.J.; CAMARGO, A.F.M. Aquatic macrophyte distribution in relation to water and sediment conditions in the Itaipu Reservoir, Brazil . **Hydrobiologia** 415: 147–154, 1999.

BIUDES, J.F.V.; CAMARGO, A.F.M. Changes in biomass, chemical composition and nutritive value of Spartina alterniflora due to organic pollution in the Itanhaém River Basin (SP, Brazil). **Brazilian Journal of Biology**, v. 66, n. 3, p. 781-789, 2006.

BOËCHAT, I. G.; PAIVA, A. B. M.; HILLE, S.; GÜCKER, B. Land-use effects on river habitat quality and sediment granulometry along a 4th-order tropical river. **Revista Ambient. Água**, v. 8, n. 3, p. 54-64, 2013.

BORNETTE, G.; PUIJALON, S. Response of aquatic plants to abiotic factors: a review. **Aquatic Sciences**, 73(1):1-14, 2011.

BOVE, C.P.; GIL, A.S.B.; MOREIRA, C.B.; ANJOS, R.F.B. Hidrófitas fanerogâmicas de ecossistemas aquáticos temporários da planície costeira do Estado do Rio de Janeiro, Brasil. **Acta Botanica Brasilica** 17(1): 119-135, 2003.

BOVINI, M.G. A new combination in the genus *Talipariti* (Malvaceae). **Rodriguésia** 61(Sup.): S19-S21, 2010.

CABREBA, A.V.; MARTÍNEZ-VILALTA, J.; RETANA, J. Functional trait variation along environmental gradients in temperate and Mediterranean trees. **Global Ecology and Biogeography** 24: 1377–1389, 2015.

CADOTTE, M.W. The new diversity: management gains through insights into the functional diversity of communities. **Journal of Applied Ecology**, 48, 1067–1069, 2011.

CADOTTE, M.W.; CARSCADDEN, K.; MIROTCHNICK, N. Beyond species: functional diversity and the maintenance of ecological processes and services. **Journal of Applied Ecology**, 48, 1079–1087, 2011.

CAMARGO, R. & HARARI, J. Modeling the Paranagua Estuarine Complex, Brazil: tidal circulation and cotidal charts. **Rev. Bras. Oceanogr**., 51:23-31, 2003.

CAFFREY, J.M.; DUTARTRE, A.; HAURY, J.; MURPHY, K.M. & WADE, P.M. **Macrophytes in Aquatic Ecosystems: From Biology to Management.** Springer Netherlands, 1 ed, 264p, 2006.

CAIRES, R.A.; PICHLER, H.A.; SPACH, H.L; IGNÁCIO, J.M. *Opsanus brasiliensis* Rotundo, Spinelli & Zavalla-Camin, 2005 (Teleostei: Batrachoidiformes: Batrachoididae), a junior synonym of Opsanus beta (Goode & Bean, 1880), with notes on its occurrence in the Brazilian coast. **Biota Neotropica** 7: 135–139, 2007.

CAMARGO, R; HARARI, J. Modeling the Paranagua Estuarine Complex, Brazil: tidal circulation and cotidal charts. **Rev. Bras. Oceanogr.,** 51:23-31, 2003.

CAMARGO, A.F.M.; PEZZATO, M.M.; HENRY-SILVA. G.G. **Fatores limitantes à produção primária de macrófitas aquáticas.** In: Thomaz, S.M. e Bini, L.M. (eds.). Ecologia e manejo de macrófitas aquáticas. pp. 59-83. Maringá: EDUEM. 2003.

CAMPELO, M.J.A.; SIQUEIRA FILHO, J.A.; COTARELLI, V.M.; SOUZA, E.B.; PIMENTA, W.A.; Pott, J.V. **Macrófitas Aquáticas nas Áreas do Projeto da Integração do Rio São Francisco.** In: SIQUEIRA-FILHO, J.A.; LEME, E.M.C. (Org.). Flora das Caatingas do Rio São Francisco. Flora das Caatingas do Rio São Francisco. Rio de janeiro: Andrea Jakobsson Estúdio Editorial Ltda, v. 1, p. 192-229, 2012.

CAMPELO, M.J.A.; SIQUEIRA-FILHO, J.A.; COTARELLI, V.M. Structure Community of Aquatic Macrophytes in Springs of the Semiarid, Northeast Brazil. **International Journal of Scientific Knowledge** 4: 20-28, 2013.

CANCIAN, L.F. **Modelagem de distribuição geográfica potencial de macrófitas aquáticas em bacias hidrográficas.** Tese de doutorado. Programa de Pós-Graduação em Ciências Biológicas (Biologia Vegetal) - Instituto de Biociências - Universidade Estadual Paulista, Rio Claro. 2012.

CAPERS, R.S.; SELSKY, R.; BUGBEE, G.J. The relative importance of local conditions and regional process in structuring aquatic plant communities. **Freshwater Biology** 55, 952-966, 2010.

CARDINALE, B.J.; DUFFY, J.E.; GONZALEZ, A.; HOOPER, D.U.; PERRINGS, C.; VENAIL, P.; NARWAI, A.; MACE, G.M.; TILMAN, D.; WARDLE, D.A.; ZINGIZ, A.P.; DAILY, G.C.; LOEAU, M.; GRACE, J.B.; LARIGAUDERIE, A.; SRIVASTAVA, D.S.; NAEEM, S. Biodiversity loss and the impact on humanity. **Nature** 486: 59-67, 2012.

CARLUCCI, M.; DEBASTIANI, V.; PILLAR, V.; DUARTE, L. Between and within-species trait variability and the assembly of sapling communities in forest patches. **Journal of Vegetation Science** 26: 21–31, 2015.

CARNIATTO, N.; THOMAZ, S.M.; CUNHA, E.R.; FUGI, R.; OTA, R.R. Effects of an invasive alien poaceae on aquatic macrophytes and fish communities in a neotropical reservoir. **Biotropica**, 45: 747–754, 2013.

CAVALLI, G.; BAATTRUP-PEDERSEN, A.; RIIS, T. The role of species functional traits for distributional patterns in lowland stream vegetation. **Freshwater Science**, 33, 1074–1085, 2014.

CERVI, A.C.; BONA, C.; MOÇO, M.C.C; VON-LINSINGEN, L. Macrófitas aquáticas do Município de General Carneiro, Paraná, Brasil. **Biota Neotrop.** 9(3): 215-222, 2009.

CESCHIN, F.; BINI, L.M.; PADIAL, A.A. Correlates of fish and aquatic macrophyte beta diversity in the Upper Paraná River floodplain. **Hydrobiologia** 805(1): 377-389, 2017.

CIANCIARUSO, M.V.; BATALHA, M.A.; GASTON, K.J. & PETCHEY, O.L. Including intraspecific variability in functional diversity. **Ecology**, 90(1): 81–89, 2009.

CIANCIARUSO, M.V.; SILVA, I.A.; BATALHA, M.A.; GASTON, K.J.; PETCHEY, O.L. The influence of fire on phylogenetic and functional structure of woody savannas: moving from species to individuals. **Perspectives in Plant Ecology, Evolution and Systematics** 14: 205-216, 2012.

CONTENTE, R.F.; STEFANONI, M.F; SPACH, H.L. Fish assemblage structure in an estuary of the Atlantic Forest biodiversity hotspot (southern Brazil). **Ichthyol Res** 58: 38–50, 2011.

CORREIA, M.A.; MAMEDE, M.C.H. **Lentibulariaceae** In: Wanderley, M.G.L., Shepherd, G.J., Giulietti, A.M., Melhem, T.S., Bittrich, V., Kameyama, C. (eds.) Flora Fanerogâmica do Estado de São Paulo. Instituto de Botânica, São Paulo, vol. 2, pp: 141-154, 2002.

CRAIN, C.M.; SILLIMAN, B.R.; BERTNESS, S.L. & BERTNESS, M.D. Physical and biotic drivers of plant distribution across estuarine salinity gradients. **Ecology**, v.85, n.9, p.2539-2549, 2004.

CRIST, T.O.; VEECH, J.A.; GERING, J.C.; SUMMERVILLE, K.S. Partitioning species diversity across landscapes and regions: a hierarchical analysis of α, β, and γ-diversity. **The American naturalist** 162: 734–743, 2003.

ELTON, C. S. **The ecology of invasions by animals and plants.** London: Methuen, 1958.

ENDRESS, A.G. Spore Germination of Ceratopteris thalictroides (L.) Brongn. **Annals of Botany New Serie**s, 38(157):877-881, 1974.

ENGELS. J.G.; JENSEN, K. Role of biotic interactions and physical factors in determining the distribution of marsh species along an estuarine salinity gradient. **Oikos** v. 119, p. 679-685, 2010.

ESTEVES, F.A. **Fundamentos de Limnologia.** Rio de Janeiro. Interciência/FINEP. 2.ed. Rio de Janeiro. 602p, 1998.

FERNANDES, U.L.; OLIVEIRA, E.C.C.; LACERDA, S.R. Role of macrophyte life forms in driving periphytic microalgal assemblages in a Brazilian reservoir. **Journal of Limnology** 75 (1): 44-51, 2016.

FERNANDES, L.F.G.; TEIXEIRA, M.C.; THOMAZ, S.M. Diversity and biomass of native macrophytes are negatively related to dominance of an invasive Poaceae in Brazilian sub-tropical streams. **Acta Limnologica Brasiliensia** 25(2): 202-209, 2013.

FERNÁNDEZ-ALÁEZ, A.; FERNÁNDEZ-ALÁEZ, M.; GARCÍA-CRIADO, F.; GARCÍAN-GIRÓN, J. Environmental drivers of aquatic macrophyte assemblages in ponds along an altitudinal gradient. **Hydrobiologia** p: 1-20, 2016.

FERREIRA, F.A.; MORMUL, R.P.; PEDRALLI, G.; POTT, V.J.; POTT, A. Estrutura da comunidade de macrófitas aquáticas em três lagoas do Parque Estadual do Rio Doce, Minas Gerais, Brasil. **Hoehnea** 37: 43–52, 2010.

FERREIRA, F.A.; MORMUL, R.P.; THOMAZ, S.M.; POTT, A.; POTT, V.J. Macrophytes in the upper Paraná river floodplain: checklist and comparison with other large South American wetlands. **Revista de Biologia Tropical** 59 (2): 541-556, 2011.

FLYNN, D.F.B.; MIROTCHNICK, N.; JAIN, M.; PALMER, M.I.; NAEEM, S. Functional and phylogenetic diversity as predictors of biodiversity-ecosystem function relationships. **Ecology**, 92, 1573–1581, 2011.

FORNARA, D.A.; TILMAN, D. Plant functional composition influences rates of soil carbon and nitrogen accumulation. **Journal of Ecology**, 96, 314–322, 2008.

FRANÇA, F.; MELO, E.; OLIVEIRA, I.B.; REIS, A.T.C.; ALVES, G.L.; COSTA, M.F. Plantas vasculares das áreas alagadas dos Marimbus, Chapada Diamantina, BA, Brasil. **Hoehnea** 37(4): 719–730, 2010.

FRITZ, C.; SCHNEIDER, T.; GEIST, J. Seasonal Variation in Spectral Response of Submerged Aquatic Macrophytes: A Case Study at Lake Starnberg (Germany). **Water** 9(521): 1-21, 2017.

FU, H.; ZHONG, J,; YUAN, G.; XIE, P.; GUO, L.; ZHANG, Z.; XU, J.; LI, Z.; LI, W.; ZHANG, M.; CAO, T.; NI, L. Trait-based community assembly of aquatic macrophytes along a water depth gradient in a freshwater lake. **Freshwater Biology** 59, 2462–2471, 2014.
FU, H.; ZHONG, J.; YUAN, G.; NI, L.; XIE, P.; CAO, T. Functional traits composition predict macrophytes community productivity along a water depth gradient in a freshwater lake. **Ecol Evol.** 4(9): 1516–1523, 2014.

FU, H.; ZHONG, J.; FANG, S.; HU, J.; GUO, C.; LOU, Q.; YUAN, G.;DAI, T.; LI, Z.; ZHANG,M.; LI, W.; XU, J.; CAO, T. Scale-dependent changes in the functional diversity of macrophytes in subtropical freshwater lakes in south China. **Scientific Reports**. 7 (8294): 1-12, 2017.

GASTAL-JR.; C.V.S.; IRGANG, B.E. Levantamento de macrófitas aquáticas do Vale do Rio Pardo, Rio Grande do Sul, Brasil. **Iheringia** 49: 3-9, 1997.

GIL, A.S.B.; BOVE, C.P. *Eleocharis* R.Br. (Cyperaceae) no Estado do Rio de Janeiro, Brasil. **Biota Neotrop.** vol.7 no.1, 2007.

GORHAM, E.; GORDON, A.G. Some effects of smelter pollution upon aquatic vegetation eear Sudbury, Ontario. **Canadian Journal of Botany**, 41(3): 371-378, 1963.

GOUVEIA-SANTOS, A. **Urochloa**. In: WANDERLEY, M.G.L.; SHEPHERD, G.J.; GIULIETTI, A.M. (orgs.). Flora Fanerogâmica do Estado de São Paulo: Poaceae. FAPESP & HUCITEC, São Paulo, v.1, pp. 243-245, 2001.

GRIMALDO, J.T.; BINI, L.M.; LANDEIRO, V.L.; O'HARE, M.T.; CAFFREY, J.; SPINK, A.; MARTINS, S.V.; KENNEDY, M.P.; MURPHY, K.J. Spatial and environmental drivers of macrophyte diversity and community composition in temperate and tropical calcareous rivers. **Aquatic Botany**. 132: 49-61, 2016.

GUGLIERI, A.; LONGHI-WAGNER, H.M. & ZULOAGA, F.O. *Panicum* Sect. *Dichotomiflora* (Hitchc. & Chase) Honda e P. sect. *Virgata* Hitchc. & Chase ex Pilg. (Poaceae: Panicoideae: Paniceae) no Brasil. **Acta Botanica Brasilica**, Porto Alegre 21(4)785-805, 207.

GUO, H.; PENNINGS, S.C. Mechanisms mediating plant distributions across estuarine landscapes in a low-latitude tidal estuary. **Ecology**, v. 93, n.1, p. 90-100, 2012.

HALL, C.F.; GIL, A.S.B. Flora das cangas da Serra dos Carajás, Pará, Brasil: Hydrocharitaceae. **Rodriguesia** 67(5): 1367-1371, 2016.

HAVEL, J.E.; KOVALENKO, K.E.; THOMAZ, S.M.; ALAMFITANO, S.; KATS, L.B. Aquatic invasive species: challenges for the future. **Hydrobiologia**. 750: 147-170, 2015.

HAYNES, R.R.; HELLQUIST,C.B. **Potamogetonaceae.** In: Flora of North America: north of Mexico, vol. 2, 1993.

HEFLER, S.M.; LONGHI-WAGNER, H.M. *Cyperus* L. subg. *Cyperus* (Cyperaceae) na Região Sul do Brasil*. R. bras. Bioci*., Porto Alegre, v. 10, n. 3, p. 327-372, 2012.

HEJDA, M.; de BELLO, F. Impact of plant invasions on functional diversity in the vegetation of Central Europe. **Journal of Vegetation Science** 24: 890-897, 2013.

HENRY-SILVA, G.G.; MOURA, R.S.T.; DANTAS, L.L.O. Richness and distribution of aquatic macrophytes in Brazilian semi-arid aquatic ecosystems. **Acta Limnologica Brasiliensis** 22(2): 147-156, 2010.

HOOPER, D.U.; CHAPIN III, F.S.; EWEL, J.J.; HECTOR, A.; INCHAUSTI, P.; LAVOREL, S.; LAWTON, J.H.; LODGE, D.M.; LOREAU, M.; NAEEM, S.; SCHMID, B.; SETALA, H.; SYMSTAD, A.J.; VANDERMEER, J.; WARDLE, D.A. Effects of biodiversity on ecosystem functioning: A consensus of current knowledge. **Ecol Monogr** 75:3–35, 2005.

JANES, H.; KOTTA, J.; PARNOJA, M.; CROWE, T.P.; RINDI, F.; ORAV-KOTTA, H. Functional traits of marine macrophytes predict primary production. **Functional Ecology** 31(4): 975-986, 2017.

KADIRI, A.B, OLOWOKUDEJO, J.D. Systematic significance of foliar epidermal morphology in the West African species of Ludwigia (Onagraceae). **Phytologia Balcanica** 16 (1): 57 – 64, 2010.

KICHENIN, E.; WARDLE, D.A.; PELTZER, D.A.; MORSE, C.W.; FRESCHET, G.T; KITAJIMA, K. Contrasting effects of plant inter and intraspecific variation on community-level trait measures along an environmental gradient. **Functional Ecology** 27:1254–1261, 2013.

KITA, K.K.; SOUZA, M.C. Levantamento florístico e fitofisionomia da lagoa Figueira e seu entorno, planície alagável do alto rio Paraná, Porto Rico, Estado do Paraná, Brasil. **Acta Scientiarum: Biological Sciences** 25(1):145-155, 2003.

KOLLMANN, L.J.C. Begoniaceae da Estação Biológica de Santa Lúcia, municipio de Santa Teresa, Estado do Espírito Santo, Brasil. **Boletim do Museu de Biologia Mello Leitão** 20: 07-25, 2006.

KOLON, K. The sensitivity of water liverworts *Riccia fluitans* L. and *Ricciocarpus natans* [L.] Corda to selected polycyclic aromatic hydrocarbons. **Acta Universitatis Wratislaviensis. Prace Botaniczne,** 79: 145-150, 2001.

LALIBERTÉ, E.; P. LEGENDRE. A distance-based framework for measuring functional diversity from multiple traits. **Ecology** 91:299–305, 2010.

LANA, P.C.; MARONE, E.L.; LOPES, L.M.; MACHADO, E.C. **The subtropical estuarine complex of Paranaguá Bay, Brazil.** In: Seeliger U, Lacerda LD, Kjerfve BJ (eds) Coastal marine ecosystems of Latin America. Springer, Berlin, p: 131–145, 2001.

LAVOREL, S.; GRIGULIS, S.K.; MCINTYRE, WILLIAMS, N.S.G.; GARDEN, D.; DORROUGH, J.; BERMAN, S.; QUÉTIER, F.; THEBAULT, A.; BONIS, A. Assessing functional diversity in the field - methodology matters! Functional **Ecology** 22:134-147, 2008.

LEES, A.C.; PERES, C.A.; FEARNSIDE, P.M.; SCHNEIDER, M.; ZUANON, J.A.S. Hydropower and the future of Amazonian biodiversity. **Biodivers Conserv** 25: 451–466, 2016.

LEUNG, R. **Distribuição de macrófitas aquáticas em relação a variáveis ambientais em ecossistemas lóticos da Bacia do rio Itanhaém.** Tese de doutorado. Programa de Pós-Graduação em Ciências Biológicas (Biologia Vegetal) – Instituto de Biociências – Universidade Estadual Paulista, Rio Claro. 2005.

LEVINE, J.M.; BREWER, J.S. & BERTNESS, M.D. Nutrients, competition and plant zonation in a New England salt marsh. **Journal of Ecology**, v.86, p.285-292, 1998.

LI, K.; WANG, L.; LI, Z.; XIE, Y.; WANG, X. & FANG, Q. Spatial and temporal variation of aquatic plant abundance: Quantifying change. **Water** 9(707): 1-17, 2017.

LIMA, C.T. **A ordem Nymphaeales no Estado da Bahia, Brasil.** Dissertação de Mestrado (Botânica)- Universidade Estadual de Feira de Santana, Feira de Santana-BA, Brasil, 2011.

LISBOA, F.F.; GASTAL-JR, C.C.S. Levantamento das macrófitas aquáticas na beira do lago Guaíba no município de Guaíba, RS/Brasil. **Caderno de Pesquisa Série Biologia** 15(1): 17-27, 2003.

LODGE, D.M. Herbivory on freshwater macrophytes. **Aquatic Botany** 41(1-3): 195-224, 1991.

LOREAU, M.; DOWNING, A.L.; EMMERSON, M.C.; GONZALEZ, A.; HUGHES, J.; INCHAUSTI, P.; JOSHI, J.; NORBERG, J.; SALA, O. **A new look at the relationship between diversity and stability. Biodiversity and Ecosystem**

Functioning. Synthesis and Perspectives (eds LOREAU, M.; NAEEM, S.; INCHAUSTI, P.), pp. 79–91. Oxford University Press, Oxford. 2002.

LORENZI, H. **Plantas daninhas do Brasil: terrestres, aquáticas, parasitas, tóxicas e medicinais.** 4. ed. Nova Odessa: Instituto Plantarum. 2008.

LOURENÇO, A.R.; BOVE, C.P. Flora do Rio de Janeiro: Hydrocharitaceae. **Rodriguésia** 68(1): 043-050, 2017.

MACARTHUR, R.H. **Geographical ecology**. Harper & Row, New York, 1972.

MALTCHIK, L.; ROLON, A.S.; SCHOTT, P. Effects of hydrological variation on the aquatic plant community in a fl oodplain palustrine wetland of southern Brazil. **Limnology** 8:23–28, 2007.

MAGNUSSON, W.E.; LIMA, A.P.; LUIZÃO, R.; LUIZÃO, F.; COSTA, F.R.C.; CASTILHO, C.V.; KINUPP, V.F. RAPELD: A MODIFICATION OF THE GENTRY METHOD FOR BIODIVERSITY SURVEYS IN LONG-TERM ECOLOGICAL RESEARCH SITES. **Biota Neotropica**, 5(2): 1-6. http://www.biotaneotropica.org.br/v5n2/pt/abstract?pointofview+bn01005022005, 2005.

MAGURRAN, A.E. **Measuring Biological Diversity**. Blackwell Publishing, 264p, 2013.

MELO, E. O gênero *Pollygonum* L. (Polygonaceae) no Estado da Bahia, Brasil. **Sitientibus,** 14: 45-55, 1996.

MELO F.P.L.; ARROYO-RODRIGUEZ, V.; FAHRIG, L.; MARTINEZ-RAMOS, M.; TABARELLI, M. On the hopefor biodiversity friendlytropical landscapes. **Trends in Ecology and Evolution** 28: 461–468, 2013.

MEYER, F.S. **O gênero *Tibouchina* Aubl. (Melastomataceae) no Estado do Paraná, Brasil.** Dissertação de Mestrado (Botânica)- Universidade Federal do Paraná, Curitiba-PR, Brasil, 2008.

MEYER, S.T.; FRANCESCHINELLI, E.V. A influência de variáveis limnológicas sobre a comunidade de macrófitas aquáticas em rios e lagoas da cadeia do Espinhaço, Minas Gerais, Brasil. **Rodriguesia** 62(4): 743-758, 2011.

MEYERS, N.; MITTERMEIER, R.A.; MITTERMEIER, C.G.; FONSECA, G.A.B.; KENT, J. Biodiversity hotspots for conservation priorities. **Nature** 403:853–858, 2000.

MICHELAN, T.S.; THOMAZ, S.M.; MORMUL, R.P.; CARVALHO, P. Effects of na exotic invasive macrophyte (tropical signalgrass) on native plant community composition, species richness and functional diversity. **Freshwater Biology** 55, 1315-1326, 2010.

MICHELAN, T.S.; THOMAZ, S.M.; BINI, L.M. Native Macrophyte Density and Richness Affect the Invasiveness of a Tropical Poaceae Species. **Plos One** 8 (3): 1-8, 2013.

MISSOURI BOTANICAL GARDEN. **Plant List**. Shaw Boulevard, St. Louis, MO, 63110 USA, 2017.

MORAES, M. D.; MONTEIRO, R. A Família Asteraceae na Planície Litorânea de Picinguaba, Ubatuba, São Paulo; **Hoehnea** 33(1): 41-78, 59, 2006.

MORMUL, R.P.; FERREIRA, F.A.; CARVALHO, P.; MICHELAN, T.S; SIQUEIRA, M.J.; THOMAZ, S.M. Aquatic macrophytes in the large, sub-tropical Itaipu Reservoir. **Revista de Biologia Tropical** 58: 1437-1452, 2010.

MOUCHET, M.A.; VILLEGER, S.; MASON, N.W.H.; MOUILLOT, D. Functional diversity measures: an overview of their redundancy and their ability to discriminate community assembly rules. **Functional Ecology** 24(4): 867-876, 2010.

MOURA-JÚNIOR, E.G.; LIMA, L.F.; SILVA, S.S.L.; PAIVA, R.M.S.; FERREIRA, F.A.; ZICKEL, C.S.; POTT, A. Aquatic macrophytes of Northeastern Brazil: Checklist, richness, distribution and life forms. **Check List** 9(2): 298-312, 2015.

MOURA-JÚNIOR, E.G.; ABREU, M.C.; SEVERI, W.; LIRA, G.A.S.T. O gradiente rio-barragem do reservatório de Sobradinho afeta a composição florística, riqueza e formas biológicas das macrófitas aquáticas?. **Rodriguesia** 62: 731-742, 2011.

MUNZ, P.A. Onagráceas. In: HOEHNE, F.C. (Ed.). **Flora Basilica**, v. 41, n. 1, p. 1-62, 1947.

MYERS, N.; MITTERMEIER, R.A.; MITTERMEIER, C.G.; FONSECA, G.A.B.; KENT, J. Biodiversity hotspots for conservation priorities. **Nature** 403:853-858, 2000.

NAEEM, S. Species redundancy and ecosystem reliability. **Conservation Biology**, 12:39–45, 1998.

NAEEM, S.; LI, S. Biodiversity enhances ecosystem reliability. **Nature**, 390, 507–509, 1997.

NEUENSCHWANDER, P.; JULIEN, M.H.; CENTER, T.D.; HILL, M.P. ***Pistia stratiotes* L. (Araceae).** In: MUNIAPPAN, R.; REDDY, G.V.P.; RAMAN, A. (Orgs). Biological Control of Tropical Weeds Using Arthropods, pp. 332–352. Cambridge University Press, London, 2009.

NUNES, L.S.C.; CAMARGO, A.F.M. Do interspecific competition and salinity explain plant zonation in a tropical estuary? **Hydrobiologia**, v.P.A.S., p:1-11, 2016.

OLIVEIRA, M.L.A.A.; NEVES, M.T.M.B.; STREHL, T.; RAMOS, R.L.R.; BUENO, O.L. Vegetação de macrófitos aquáticos das nascentes do Rio Gravataí (Banhado Grande e Banhado Chico Lomã), Rio Grande do Sul, Brasil – Levantamento Preliminar. **Iheringia.** Série Botânica 38: 67-80, 1988.

O'HARE, M.T.; AGUIAR, F.C.; ASAEDA, T.; BAKKER, E.S.; CHAMBERS, P.A.; CLAYTON, J.S.; ELGER, A.; FERREIRA, T.M.; GROSS, E.M.; GUNN, I.D.M.; GURNELL, A.M.; HELLSTEN, S.; HOFSTRA, D.E.; LI, W.; MOHR, S.; PUIJALON, S.; SZOSZKIEWICZ, K.; WILLBY, N.J.; WOOD, K.S. Plants in aquatic ecosystems: current trends and future directions. **Hydrobiologia.** 1-11. DOI 10.1007/s10750-017-3190-7, 2017.

PADIAL, A.A.; CARVALHO, P.; THOMAZ, S.M.; BOSCHILIA, S.M.; RODRIGUES, R.B. & KOBAYASHI, J.T. The role of an extreme flood disturbance on macrophyte assemblages in a Neotropical floodplain. **Aquatic Sciences** 71(4): 389-398, 2009.

PAVÃO, A.C.; SANTOS, A.C.A.; BOTTINO, F.; BENASSI, R.F.; CALIJURI, M.C. Richness and distribution of aquatic macrophytes in a subtropical reservoir in São Paulo, Brazil. **Acta Limnologica Brasiliensia** 29(10): 1-11, 2017.

PEDRALLI, G. Macrófitos aquáticos: técnicas e métodos de estudos. **Estudos de Biologia** 26: 5-24, 1990.

PELICICE, F.M.; AGOSTINHO, A.A. Fish fauna destruction after the introduction of a non-native predator (Cichla kelberi) in a Neotropical reservoir. **Biological Invasions** 11: 1789–1801, 2009.

PELICICE, F.M.; VITULE, J.R.S.; LIMA, D.P.; ORSI, J.M.L.; AGOSTINHO, A.A. A serious new threat to Brazilian freshwater ecosystems: the naturalization of nonnative fish by decree. **Conservation Letters** 7: 55–60, 2014.

PÉREZ-HARGUINDEGUY, N.; DÍAZ, S.; GARNIER, E.; LAVOREL, S.; POORTER, H.; JAUREGUIBERRY, P.;.BRET-HARTE, M.A.; CORNWELL, W.K.; CRAINE, J.M.; GURVICH, D.E.; URCELAY, C. VENEKLAAS, E.J.; REICHI, P.B.; POORTER, L.; WRIGHT, I.J.; RAY, P.; ENRICO, L.; PAUSAS, J.G.; DE VOS, A.C.; BUCHMANN, N.; FUNES, G.; QUÉTIER, F.; HODGSON, J.G.; THOMPSON, K.; MORGAN, H.D.; TER STEEGE, H.; VAN DER HEIJDEN, M.G.A.; SACK, L.; BLONDER, B.; POSCHLOD, P.; VAIERETTI, M.V.; CONTI, G.; STAVER, A.C.; AQUINO, S. AND CORNELISSEN, J.H.C. New handbook for standardised measurement of plant functional traits worldwide. **Australian Journal of Botany** 61, 167–234, 2013

PETCHEY, O.L.; GASTON, K.J. Functional diversity: back to basics and looking forward. **Ecol. Lett.** Jun;9(6):741-58, 2006.

PETCHEY, O.L.; GORMAN, E.J.O.; FLYNN, D.F.B. **A functional guide to functional diversity measures.** In: Naeem S, Bunker DE, Hector A, Loreau M, Perrings C. (eds.) Biodiversity, ecosystem functioning and human wellbeing: An ecological and economic perspective. Oxford, Oxford University Press. p. 49-59, 2009.

PITELLI, R.L.C.M.; TOFFANELI, C.M.; VIEIRA, E.A.; PITELLI, R.A.; VELINI, E.D. Dinâmica da comunidade de macrófitas aquáticas no reservatório de Santana, RJ. Viçosa. **Planta daninha**, v. 26, p. 473-480, 2008.

PIVARI, M.O.; OLIVEIRA, V.B.; COSTA, F.M.; FERREIRA, R.M.; SALINO, A. Macrófitas aquáticas do sistema lacustre do Vale do Rio Doce, Minas Gerais, Brasil. **Rodriguésia** 62 (4): 759-770, 2011.

POMPÊO, M.L.M. Monitoramento e manejo de macrófitas aquáticas. **Oecologia Brasiliensis** 12: 406–424, 2008.
POMPÊO, M.L.M.; MOSCHINI-CARLOS, V**. Macrófitas aquáticas e perifíton: aspectos ecológicos e metodológicos.** São Carlos: RiMa Editora. 134p, 2003.

POTT, V.J.; POTT, A.; LIMA, L.C.P.; MOREIRA, S.N.; OLIVEIRA, A.K.M. Aquatic macrophyte diversity of the Pantanal wetland and upper basin. **Brazilian Journal of Biology** 1: 255-263, 2011.

POTT, V.J; POTT, A. **Plantas aquáticas do Pantanal.** Brasília: EMBRAPA. 353p, 2000.

RAMAMOORTHY, T.P.; ZARDINI, E.M. The systematics and evolution of *Ludwigia* sect. *Myrtocarpus* sensu lato. **Monograph Systematic Botany. (Missouri Botanical Garden),** 19:1-120, 1987.

RAUNKIAER, C. **The life forms of plants and statistical plant geography.** Oxford: Claderon Press. 632p, 1934.

RIBEIRO, J.P.N.; TAKAO, L.K.; MATSUMOTO, R.S.; URBANETZ, C.; LIMA, M.I.S. Plantae, aquatic, amphibian and marginal species, Massaguaçu River Estuary, Caraguatatuba, São Paulo, Brazil. **Check List** 7(2): 133- 138, 2011.

QUEIROZ, F. L. L.; ROCHA, P. C. Avaliação de sedimentos do leito no canal Curutuba / planície fluvial do alto rio Paraná, Mato Grosso do Sul - Brasil. **Revista AGB/TL**, v. 7, n. 11, p. 147-164, 2010.

R Core Team. 2017. R: **A language and environment for statistical computing.** http:// www.R–project.org/.

RIIS, T.; LAMBERTINI, C.; OLESEN, B.; CLAYTON, J.S.; BRIX, H.; SORREL, B.K. Invasion strategies in clonal aquatic plants: are phenotypic differences caused by phenotypic plasticity or local adaptation? **Annals of Botany,** 106(5): 813-822, 2010.

ROCHA, D.C.; MARTINS, D. Levantamento de plantas daninhas aquáticas no Reservatório de Alagados, Ponta Grossa-Pr. **Planta Daninha** 29(2): 237-246, 2011.

ROCHA, F.S.; WAECHTER, J.L. Sinopse das Orchidaceae terrestres ocorrentes no litoral norte do Rio Grande do Sul, Brasil. **Acta Botanica Brasilica.** 20(1): 71-86, 2006.

RODRIGUES, M.E.F. **Levantamento Florístico e distribuição de macrófitas aquáticas na Represa Guarapiranga, São Paulo, Brasil.** Dissertação de mestrado (Botânica) – Universidade de São Paulo, São Paulo-SP, Brasil, 2011.

RODRIGUES, A. S. L.; MALAFAIA, G.; CASTRO, P. T. A. A importância da avaliação do habitat no monitoramento da qualidade dos recursos hídricos: uma revisão. **SaBios**, v. 5, n. 1, p. 26-42, 2010.

ROLON, A.S.; HOMEM, H.F; MALTCHIK. Aquatic macrophytes in natural and managed wetlands of Rio Grande do Sul State, Southern Brazil. **Acta Limnol.** Bras. 22(2): 133-146, 2010.

ROLON, A.S.; ROCHA, O.; MALTCHIK, L. Diversidade de macrofitas aquáticas do Parque Nacional da Lagoa do Peixe. **Neotropical Biology and Conservation** 6: 5-12, 2011.

ROY, S.; IHANTOLA, R.; HANNINEN, O. Peroxidase activity in lake macrophytes and its relation to pollution tolerance. **Environmental and Experimental Botany** 32(4): 457-464, 1992.

SABINO, J.H.F.; ARAUJO, E.S.; COTARELLI, V.M.; SIQUEIRA-FILHO, J.A.; CAMPELO, M.J.A. Riqueza, composição florística, estrutura e formas biológicas de macrófitas aquáticas em reservatórios do semiárido nordestino, Brasil. **Natureza on line** 13(4): 184-194, 2015.

SALINO, A.; ARRUDA, A.J. Flora das cangas da Serra dos Carajás, Pará, Brasil: Lycopodiaceae. **Rodriguésia** 67(5):1159-1161, 2016.

SAX, D.F.; GAINES, S.D. Species diversity: from global decreases to local increases. **Trend in Ecology and Evolution** 18(11):561-566, 2003.

SCHLEUTER, A.D.; DAUFRESNE, M.; MASSOL, F.; ARGILLIER, C.; MONOGRAPHS, S.E.; AUGUST, N. A user‘s guide to functional diversity indices A user‘s. **Ecological Monographs** 80:469–484. 2014.

SCHMERA, D.; BAUR, B.; ERÕS, T. Does functional redundancy of communities provideinsurance against human disturbances? An analysis usingregional-scale stream invertebrate data. **Hydrobiologia** 693(1): 183-194, 2012.

SCHULTZ, R.; DIBBLE, E. Effects of invasive macrophytes on freshwater fish and macroinvertebrate communities: the role of invasive plant traits. **Hydrobiologia** 684(1): 1-14, 2012.

SÉRGIO, C.; BRUGUÉS, M.; CROS, C.; GARCIA, C. The 2006 Red List and an updated Checklist of bryophytes of the Iberian Peninsula (Portugal, Spain and Andorra). **Lindbergia** 31: 109-125, 2006.

SILVA, C.O. **Características anatômicas e fisiológicas de *Thypa dominguensis* Pers. submetida a concentrações de arsênio.** Dissertação de Mestrado (Botânica Aplicada) – Universidade Federal de Lavras, Lavras-MG, Brasil. 2014.

SILVA, F.F.G. **Composição e distribuição da ictiofauna do Rio Guaraguaçu (Paranaguá, Paraná-BR) e biologia alimentar de três espécies.** Mestrado em Zoologia, Universidade Federal do Paraná, Curitiba, 2008.

SILVEIRA, G.H.; LONGHI-WAGNER, H.M. Cyperaceae Juss. no Morro Santana – Porto Alegre e Viamão, Rio Grande do Sul, Brasil. **Iheringia, Sér. Bot.** 63(2):295-320, 2008.

SIQUEIRA-FILHO, J.A. **Flora das Caatingas do Rio São Francisco : História natural e conservação.** 1. ed. Rio de Janeiro, 552p, 2012.

SLOVENSKI, A.C. **Aspectos fitossociolôgicos e pedológicos de três superfícies de agradaçào do rio Guaraguaçu, litoral do Paraná.** Dissertação Mestrado em Ciências Florestais. Universidade Federal do Paraná, Curitiba, 2000.

SMITH, A.R.; PRYER, K.M.; SCHUETTPELZ, E.; KORALL, P.; SCHNEIDER, H.; WOLF, P.G. A classification for extant ferns. **Taxon** 55: 705-731, 2006.

SOCOLAR, J,B.; GILROY, J.J.; KUNIN, W.E.; EDWARDS, D.P. 2016. How Should Beta-Diversity Inform Biodiversity Conservation?. **Trends in Ecology & Evolution** 31(1): 67-80

SOBRAL-LEITE, M.; CAMPELO, M.J.A.; SIQUEIRA-FILHO, J.A.; SILVA, S.I. **Checklist das macrófitas vasculares de Pernambuco: Riqueza de espécies, formas biológicas e considerações sobre distribuição.** In: ALBUQUERQUE, U.P.; MOURA, A.N.; ARAÚJO, E.L. (org.). Biodiversidade, potencial econômico e processos eco-fisiológicos em ecossistemas nordestinos. Recife, Ed. Nupeea, 255-280, 2010.

SOUZA, V.C.; LORENZI, H. **Botânica Sistemática: Guia ilustrado para identificação das famílias de Angiospermas da flora brasileira, baseado em APG II.** 2ª Ed. Nova Odessa, Instituto Plantarum, 704p, 2008.

SOUZA, T.A.; OLIVEIRA, R.C. Alterações ambientais no complexo estuarino-Lagunar de Cananeia-Iguape: a influência do canal artificial do “valo grande”. **Boletim de Geografia** 34(12): 30-44, 2016.

SPASOJEVIC, M.J.; TURNER, B.L.; MYERS, J.A. When does intraspecific trait variation contribute to functional beta-diversity?. **Journal of Ecology**, 104, 487–496, 2016.

STATSOFT, INC. **STATISTICA** (data analysis software system), version 7.1. www.statsoft.com. 2005.

THOMAZ, S.M.; BINI, L.M. **Análise crítica dos estudos sobre macrófitas aquáticas desenvolvidos no Brasil;** p: 19-38. In: THOMAZ, S.M.; BINI, L.M. (eds.). Ecologia e manejo de macrófitas aquáticas. Maringá: Eduem. 2003.

STURZA, V.S.; MACHADO, S.L.O.; SILVA, K.S.; SANTOS, A.B. Forage quality of 'capim-capivara' on lowlands in the central region of Rio Grande do Sul, Brazil. **Ciência Rural**, Santa Maria, Online, 2011.

THOMAZ, S.M.; SOUZA, D; BINI, L.M. Species richness and beta diversity of aquatic macrophyte in a large subtropical reservoir (Itaipu Reservoir, Brazil): the influnce of limnology and morfometry. **Hydrobiologia** 505: 119-128., 2003

TILMAN D. **Functional diversity.** In: Levin, S.A. (ed.) Encyclopedia of Biodiversity. San Diego, Academic Press. p. 109-120, 2001.

TOLEDO, J.J.; PENHA, J. Performance of Azolla caroliniana Willd. and Salvinia auriculata Aubl. on fish farming efluente. **Braz. J. Biol.** 71(1), 2011.

UJOWUNDU, C.O.; IGWE, C.U.; ENEMOR, V.H.A; NWAOGU, L.A.; OKAFOR, O.E. Nutritive and Anti-Nutritive Properties of *Boerhavia diffusa* and *Commelina nudiflora* Leaves**. Pakistan Journal of Nutrition** 7 (1): 90-92, 2008.

VILLÉGER S.; MASON N.W.H.; MOUILLOT, D. New multidimensional functional diversity indices for a multifaceted framework in functional ecology. **Ecology**, 89, 2290–2301, 2008.

VIOLLE, C., NAVAS, M.-L., VILE, D., KAZAKOU, E., FORTUNEL, C., HUMMEL, I. & GARNIER, E. 2007. Let the concept of trait be functional! **Oikos**, 116, 882–892.

VITOUSEK, P.M.; MOONEY, H.A.; LUBCHENCO, J. & MELILLO, J.M. 1997. Human Domination of Earth's Ecosystems. **Science, New Series**, 277(5325): 494-499

VITULE, J.R.S. **Distribuição, abundância e estrutura populacional de peixes introduzidos no Rio Guaraguaçu, Paranaguá, Paraná, Brasil.** Tese de Doutorado (Zoologia), Universidade Federal do Paraná, Curitiba, Paraná. 161p, 2007.

VITULE, J.R.S.; AZEVEDO-SANTOS, V.M.; DAGA, V.S.; LIMA-JUNIOR, D.P.; MAGALHÃES, A.L.B.; ORSI, M.L.; PELICICE, F.M.; AGOSTINHO, A.A. Brazil's drought: protect biodiversity. **Science** 347: 1427–1428, 2015.

VITULE, J.R.S.; BORNATOWSKI, H.; FREIRE, C.A.; ABILHOA, V. Extralimital introductions of *Salminus brasiliensis* (Cuvier, 1816) (Teleostei, Characidae) for sport fishing purposes: a growing challenge for the conservation of biodiversity in neotropical aquatic ecosystems. **Biological Invasions Rec** 3(4): 291–296, 2014.

VITULE, J.R.S.; UMBRIA, S.C.; ARANHA, J.M.R. Introduction of the African catfish *Clarias gariepinus* (Burchell, 1822) into Southern Brazil. **Biol Invations** 8: 677–681, 2006.

VORONTSOVA, M.S.; CLAYTON, D. & SIMON, B.K. 2015. Grassroots e-floras in the Poaceae: growing GrassBase and GrassWorld. **PhytoKeys** (48): 73–84, 2015.

WARD, J. V.; STANFORD, J. A. **The serial discontinuity concept in lotic ecosystems.** *In*: Fontaine, T. D.; Barthell, S. M. (Eds.). *Dynamics of lotic ecosystems*. Michigan: Ann Arbor Science, 1983.

WEBB, C. O.; ACKERLY, D. D.; MCPEEK, M. A.; DONOGHUE, M. J. Phylogenies and community ecology. **Annual Review of Ecology and Systematics**, Palo Alto, 33(1): 475-505, 2002.

WETZEL, R.G. **Limnology**. San Diego: Academic Press. 1006 p, 2001.

WOLTERS, J.W. VERDONSCHOT, R.C.M., SCHOELYNCK, J., VERDONSCHOT, P.F.M. & MEIRE, P. “in press” The role of macrophyte structural complexity and water flow velocity in determining the epiphytic macroinvertebrate community composition in a lowland stream. **Hydrobiologia** 806 (1): 157-173.